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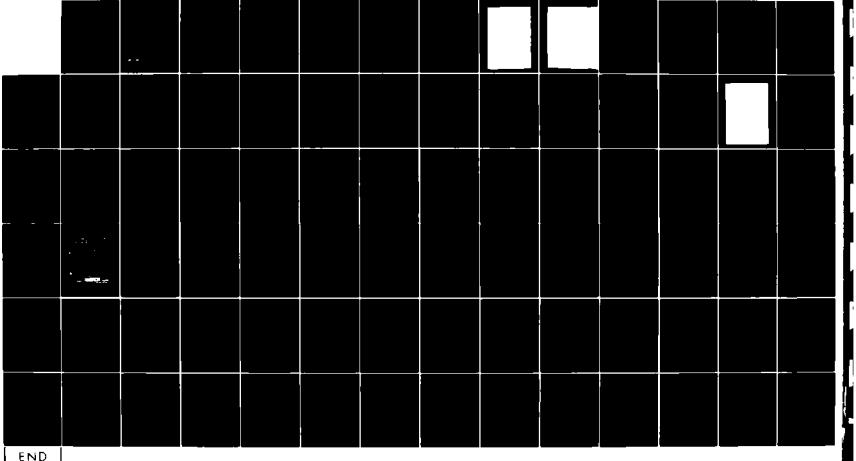

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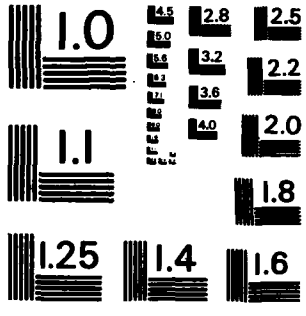

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The "6th European Conference on Visual Perception" has dealt with the following topics: spatial and temporal frequencies, color, visual physiology (cortical and subcortical), motion perception, binocular interactions, stereopsis and oculomotor proprioception.

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Pisa, November 30, 1983

FINAL SCIENTIFIC REPORT

The "6th European Conference on Visual Perception" has taken place at Castelvecchio Pascoli, Lucca, Italy, from the 28th to the 31st of August 1983.

Attendance

The Conference has been attended by more than 200 scientists, from European countries (174), U.S.A. (18), Canada (7), Australia (3) and Japan (3).

Program

The program included a Symposium on the Role of Oculomotor Proprioception in Vision, two invited general lectures, 16 sessions of contributed papers and a poster session.

Symposium

The Symposium was chaired by prof. Marc Jeannerod, Bron, France and included six invited lectures on various electrophysiological and behavioural investigations on the role of oculomotor proprioceptive information in vision. The general discussion showed the considerable interest raised in the audience by the increasing evidence in favour of a role of inflow signals in visual functions. The discussion dealt, in particular, with the possible role of proprioception in the control of binocular convergence and in spatial orientation. The need for further research both in the animal and in humans emerged clearly from the discussion and it has been suggested that investigations on possible visual or visuomotor deficits in patients with lesions of oculomotor proprioceptive fibres could be enlighting.

Invited general lectures

The invited general lectures were given by prof. D.M. MacKay (introductory lecture) on What is so odd about seeing? and by

Dr. A.P. Ginsburg on: A physics of form perception.

Scientific sessions

The scientific sessions included 76 papers, that had been selected by an international committee of referees:

Prof. Giovanni BERLUCCHI
Istituto di Fisiologia umana
Università di Pisa
Via S. Zeno, 31
56100 - Pisa, Italy

Dr Claude BONNET
Laboratoire de Psychologie Expérimentale
Université René Descartes
28, rue Serpente
7006 - Paris, France

Dr Oliver J. BRADDICK
Psychological Laboratory
University of Cambridge
Downing Street
Cambridge CB2 3EG
Great Britain

Dr C.R. CAVONIUS
Institut für Arbeitsphysiologie
an der Universität Dortmund
Ardeystrasse 67
4600 Dortmund, West Germany

Prof. Adriana FIORENTINI
Istituto di Neurofisiologia del C.N.R.
Via S. Zeno, 51
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Prof. Guy ORBAN
Laboratorium voor Neuro- en Psychofysiologie
Katholieke Universiteit Leuven
Campus Gasthuisberg
3000 Leuven, Belgium

Prof. Lothar SPILLMANN
Abteilung klinische Neurologie und Neurophysiologie
Klinikum der Albert-Ludwigs-Universität
7800 - Freiburg i. Br., West Germany

Dr J.J. VOS
Institute for Perception TNO
Kampweg 5, Postbus 23
3769 ZG Soesterberg, The Netherlands

The topics covered were: spatial and temporal frequencies, colour, physiology: cortical and subcortical, motion perception, binocular interactions and stereopsis,....

Throughout the Meeting there has been much interaction between psychophysicists and neurophysiologists.

In the poster session about 40 posters were displayed.

Abstracts

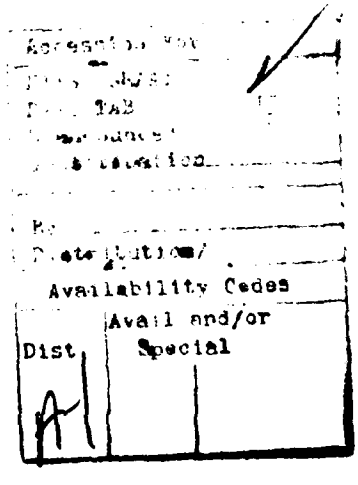
The abstracts of lectures, papers and posters will be published in "Perception" and reprints were available for the participants at the Meeting.

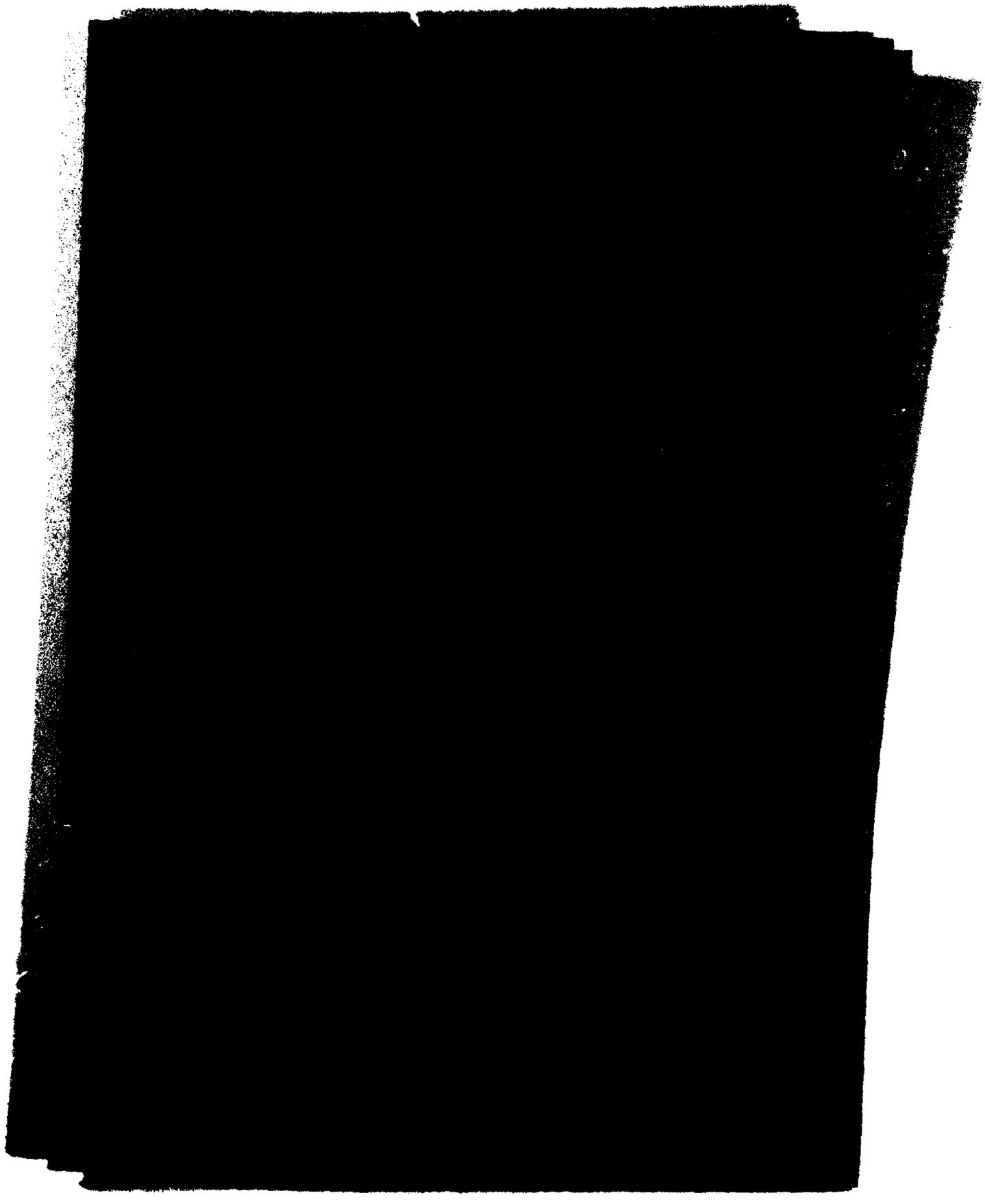
Future meetings

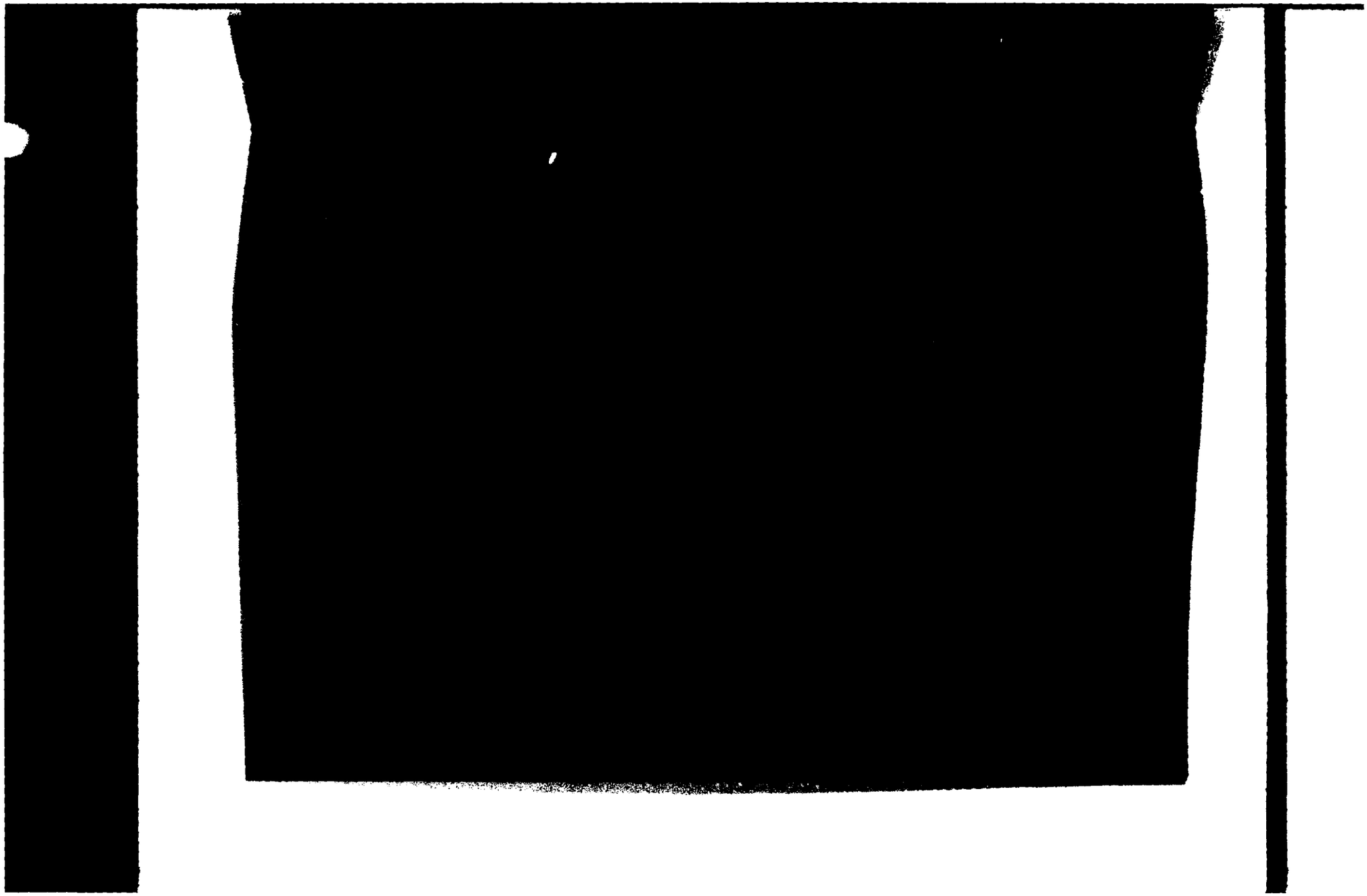
The organisation of future ECVP's was discussed at a Business Meeting during the Conference. The 1984 ECVP will be organized by Dr Oliver J. BRADDICK of the Laboratory of Experimental Psychology, University of Cambridge, Great Britain. Prof. M. AGUILAR of the University of Valencia, Spain, has offered to organize the 1985 ECVP.

Enclosures

1) Program of the 6th ECVP
2) List of participants of the 6th ECVP
3) Abstract of papers and posters presented at the 6th ECVP







6th European Conference on Visual Perception

August 28-31, 1983

Il Ciocco, Castelvecchio Pascoli (Lucca), Italy

Local Committee: A. Fiorentini, Pisa, Organizer; T. Arecchi, Florence; G. Berlucchi, Pisa; L. Foà, Pisa; W. Gerbino, Padova; L. Maffei, Pisa.

Executive Staff: A. Fiorentini, M. Benvenuti, G. Bottaro, T. Cenni, M. Giuliano, A. Tacchi.

International Committee: C. Bonnet, Paris; O.J. Braddick, Cambridge; C.R. Cavonius, Dortmund; A. Fiorentini, Pisa; J. Mollon, Cambridge; G.A. Orban, Leuven; L. Spillman, Freiburg; J.J. Vos, Soesterberg.

Sunday 28 August

15.30: Departure of coaches from Pisa (Piazza Stazione, in front of the railway station) to Il Ciocco

15 - 20: Registration at the Conference Center: Il Ciocco

20.00: Dinner

21.30 Introductory invited lecture. Prof. D.M. MacKay: What is so odd about seeing?

Monday 29 August

SYMPOSIUM ON THE ROLE OF OCULOMOTOR PROPRIOCEPTION IN VISION
Chairman: M. Jeannerod

8.50 Introductory remarks

9.00 SALINGER, W.L.: The influence of nonretinal components of monocular paralysis on the physiology of the mature Lateral Geniculate Nucleus

9.30 ASHTON, J.A., BODDY, A. and DONALDSON, I.M.L.: Extra-ocular muscle proprioceptive signals reach the vestibular eye-movement control system

9.30 - Units in cat primary visual cortex respond preferentially to particular directions of passive-movements

10.00 SKAVENSKI, A.: Accuracy and timing of information in a visual localization task requiring the use of non-retinal eye position information

10.30 Break

11.00 FIORENTINI, A. and MAFFEI, L.: Role of extraocular proprioception in visually guided behaviour of cats

11.30 HEIN, A.: Efference to and afference from extraocular muscles are critical to development in visual guidance in cats

12.00 BUISSERET, P.: Roles of sensory signals from extra-ocular muscles in developmental processes of visual cortical cells properties

12.30 General discussion

13.00 Lunch

Monday 29 August

Session A1: SPATIAL AND TEMPORAL FREQUENCIES, 1

14.30 NYMAN, G., LAURINEN, P. and RADIL, T.: Perceived contrast of pulse modulated gratings

14.50 LAURINEN, P. and NYMAN, G.: Spatial integration of raster-sampled gratings

15.10 THOMPSON, P.: Spatio-temporal tuning of channels from detection-discrimination experiments

15.30 PELLI, D.G. and WATSON, A.B.: Temporal frequency channels in vision revealed by noise masking

15.50 BARR, M.: A comparison of reaction time and temporal order judgement estimates of latency to sinusoidal gratings

16.10 Break

Session A2: SPATIAL AND TEMPORAL FREQUENCIES, 2

16.40 JASHINSKI, W.: A multiple channel model explains the detection of low-frequency complex gratings

17.00 HIRSCH, J. and HILTON, R.: Quality of the primate photoreceptor lattice and limits of spatial vision

17.20 GINSBURG, A.: Contrast sensitivity predicts the detection of complex targets

17.40 GOREA, A. and TYLER, C.W.: Modeling Bloch's law for contrast

18.00 TREUTWEIN, B., RENTSCHLER, I. and CAELLI, T.: Visual sensitivities to two-dimensional frequency differences

20.00 Dinner

21.30 Business meeting

Monday 29 August

Session B1: COLOUR 1

14.30 GOURAS, P. and EGGERS, H.: Testing color opponent theory in the retina

14.50 LEE, B.B., VALBERG, A. and TIGWELL, D.A.: Luminance-response curves and spectral selectivity of cells in the parvocellular layers of the Macaque Lateral Geniculate Nucleus

15.10 PAUL, R.: Fourierinterferometric measurement of the scotopic and photopic spectral sensitivity in man

15.30 HOLLIDAY, I.E. and RUDDOCK, K.H.: Contributions of chromatic increment threshold (π) mechanisms to two spatio-temporal filters in human vision

15.50 RICHTER, K.: Non-linear relationship between large and small chromaticness differences of an equiluminous color series

16.10 Break

Session B2: COLOUR 2

16.40 MATHER, G., CAVANAGH, P. and ANSTIS, S.: Screening for colour-blindness using optokinetic nystagmus

17.00 SPERLING, H.G. and WRIGHT, A.A.: Hue discrimination by a Rhesus with chronic, unilateral, induced tritanopia

17.20 EYSEL, U. Th. and BURANDT, U.: Visual neurons respond differently to light from fluorescent tubes and incandescent lamps

17.40 ROEHLER, R., SCHILL, W., PERIZONIUS, E. and GEIGER, H.: Does the visual system perform global or local spectrum analysis of luminance and color patterns?

18.00 FACH, C. and SPILLMANN, L.: Hue shifts in color gratings depend on spatial frequency

20.00 Dinner

21.30 Business meeting

Tuesday 30 August

Session A3: PHYSIOLOGY: CORTICAL

8.50 NOTHDURF, H.C.: Different measures of visual acuity in area 17 cells

9.10 TIGWELL, D.A. and LEE, B.B.: Monocular receptive-field structure of binocular simple cells in cat striate cortex: a comparison of the two eyes

9.30 DEAN, A.F. and TOLHURST, D.J.: On the distinctiness of simple and complex cells in the striate cortex of the cat

9.50 BISTI, S., CARMIGNOTO, G., GALLI, L., MAFFEI, L. and PIRCHIO, M.: Correlation between space and time in cat area 17 and 18

10.10 LEVI, D.M., MANNY, R.E., KLEIN, S.A. and STEINMAN, S.B.: Electrophysiological responses to vernier offset in human visual cortex

10.30 Break

Session A4: PHYSIOLOGY: CORTICAL AND SUBCORTICAL

11.00 MAFFEI, L., BISTI, S., BERARDI, N. and GALLI, L.: Spatial and temporal information transmitted through the corpus callosum

11.20 PERRETT, D.I., SMITH, P.A.J., MILNER, D. and JEEVES, M.A.: Visual cells sensitive to face orientation and direction of eye gaze in the Macaque monkey

11.40 RAUSCHECKER, J.P.: Foveofugal organization of direction selectivity in the second visual system of the cat

12.00 LEPORE, F., BEDARD, S., DI STEFANO, M., MARZI, C.A. and MOLOTCHNIKOFF, S.: Lack of binocularity in area 19 of Siamese cats

12.20 MUCKE, L., ALBOWITZ, B., BENEDEK, G., NORITA, M. and CREUTZFELDT, O.: Anterior Ectosylvian Visual Area (AEV): receptive field properties

13.00 Lunch

Tuesday 30 August

Session B3: MOTION PERCEPTION

8.50 CAVANAGH, P., BOEGLIN, J. and FAVREAU, O.E.: Perception of motion in equiluminous kinematograms

9.10 WATSON, A.B. and AHUMADA, A.J..Jr.: A linear motion sensor

9.30 KRONAUER, R.E., DAUGMAN, J.G. and ZEEVI, Y.Y.: Fourier synthesis of spatio-temporal textures: perceptual complexity, coherence, and chaos

9.50 BISCHOF, W.F. and GRONER, M.: Apparent motion beyond the displacement limit: an analysis of short-range processes

10.10 ROGERS, B.J. and GRAHAM, M.E.: Dynamic occlusion in the perception of depth structure

10.30 Break

Session B4: BINOCULAR INTERACTIONS AND STEREOPSIS

11.00 PIANTANIDA, T., HAMMON, R. and CRANE, H.: Persistence of depth perception with stabilized images

11.20 BONNET, C. and WILLIAMS, D.: Configurations of motion in dichoptic vision

11.40 GRAHAM, M.E. and ROGERS, B.J.: Phase-dependent and phase-independent depth aftereffects

12.00 SWANSTON, M.T. and WADE, N.J.: Binocular interaction in induced movement

12.20 DE WEERT, Ch. M.M.: Dichoptic cancelling of opponent movements

13.00 Lunch

Tuesday 30 August

14.30 Invited lecture. GINSBURG, A.P.: A physics of form perception

15.15 Poster session

17.00 Break

Session A5: MODELING AND VISUAL INFORMATION PROCESSING

17.30 HARVEY, L.O.: The processes of letter recognition

17.50 ROEHLER, R., SCHILL, W., FISCHER, B. and SIMMERL, H.: Image analysis with local spatial frequency channels

18.10 THOMAS, J.P.: Basic functions of a vector model of visual discrimination

18.30 HUEBNER, M. and CAELLI, T.: Tuning properties of masking functions for 2D image discrimination

18.50 CAELLI, T.M.: Coding images in the frequency domain: filter design and energy processing characteristics of the human visual system

20.30 Dinner

Tuesday 30 August

Session B5, ADAPTATION AND COLOUR

17.30 NORDBY, K., STABELL, B. and STABELL, U.: Dark-adaptation of the human rod system

17.50 VOLBRECHT, V.J., WERNER, J.S. and KLIEGL, R.: Effect of age-correlated changes in lenticular and macular pigmentation on dichromatic neutral points

18.10 WASSERMAN, G.S. and WANG, L.T.: Light adaptation alters the relation between critical durations and latencies of photoreceptor response

18.30 GERLING, J. and SPILLMAN, L.: Prolonged visual after-images with luminance modulation of the surround

18.50 VROLIJK, P.C. and van der WILDT, G.J.: The influence of the background on the propagation of inhibition

20.30 Dinner

Wednesday 31 August

Session A6, VISUAL DEVELOPMENT

8.40 VITAL-DURAND, F. and BLAKEMORE, C.: Maturation of spatial resolution and contrast sensitivity in the monkey's visual cortex

9.00 SIRETEANU, R., KELLERER, R. and BOERGEN, K.P.: The development of peripheral visual acuity in human infants

9.20 PIRCHIO, M. and FIORENTINI, A.: Development of pattern ERG in infants

9.40 ATKINSON, J., BRADDICK, O.J. and WATTAM-BELL, J.: Infants' discrimination of spatial phase in compound gratings

10.00 BAGNOLI, P., PORCIATTI, V. and BARSELLOTTI, R.: The development of spatial resolution in the pigeon retina

10.20 Break

Session A7: AMBLYOPIA - STRABISMUS

10.50 MEHDORN, E;: Nasal hemianopia in deep amblyopia

11.10 HEARD, P.F. and GREGORY, R.L.: Loss of acuity for stripes and letters at isoluminance

11.30 WEISS, C., RENTSCHLER, I. and STRASBURGER, H.: Amblyopic sensitivity to one- and two-dimensional spatial phase

11.50 APKARIAN, P., COLLEWIJN, H., SPEKREIJSE, H. and TAMMINGA, E.P.: Optik pathway anormalities and oculomotor disturbances in human albinism

12.10 CAMPOS, E.C. and CHIESI, C.: Binocular visual perception in strabismics studied by means of visual evoked responses

12.30 MOHN, G., van HOF-van DUIN, J. and SIRETEANU, R.: Asymmetry of monocular optokinetic nystagmus in humans with defective binocular vision

13.00 Lunch

Wednesday 31 August

Session B6, VISUAL ILLUSIONS

8.40 TROSCIANKO, T.: Local and global processes in the Hermann grid illusion

9.00 LINGELBACH, B., DE VALOIS, R.L. and CHAN, H.: Are visual illusions caused by spatial filtering?

9.20 METELLI, F.: Three perceptual illusions: their meaning for perceptual theory

9.40 von der HEYDT, R., PETERHANS, E. and BAUMGARTNER, G.: Correlates of the perception of contour in the activity of cells in monkey visual cortex

10.00 TEUBER, M.L.: Cézanne and Helmholtz

10.20 Break

Session B7: PERIPHERAL VISION

10.50 SCHMIELAU, F., SCHMIELAU-LUGMAYR, M.F. and MARZI, C.A.: Mirror-symmetric facilitation opposite to the blind spot

11.10 RANINEN, A. and ROVAMO, J.: Critical flicker frequency as a function of eccentricity in man

11.30 ROVAMO, J., LEINONEN, L. and VIRSU, V.: Photopic contrast sensitivity as a function of exposure duration at different eccentricities

11.50 BERARDI, N. and FIORENTINI, A. Interhemispheric difference in complex gratings discrimination

12.10 WRIGHT, M.J. and JOHNSTON, A.J.: Uniformity of motion aftereffects and lower threshold of motion in near peripheral and central visual fields

12.30 HOWARD, I.P. and OHMI, M.: The induction of opto-kinetic nystagmus by central and peripheral stimuli

13.00 Lunch

Wednesday 31 August

Session A8

14.30 ARECCHI, F.T., MEUCCI, R. and RONCHI, L.R.: An experiment on multistable fluctuations of visual response

14.50 BOSSOMAIER, T.R.J. and SNYDER, A.W.: Pictorial simulation of the visual image at the photoreceptor level

15.10 STRASBURGER, H. and RENTSCHLER, I.: Electrophysiological measurement of spatial phase sensitivity

15.30 End of the Conference

Departure of coaches from Il Ciocco to Pisa

Wednesday 31 August

Session B8

14.30 TREPP, J.P. and GERBER, A.: The detection of dynamically occurring depressions in surfaces

14.50 BURTON, G.J.: Form matching in human vision

15.10 EHRENSTEIN, W.H.: Westheimer functions for incremental and decremental visual time thresholds

15.30 End of the Conference

Departure of coaches from Il Ciocco to Pisa

POSTER SESSION

1. ADAMCZYK, R.: FIS-measurements of spectral sensitivities of man compared to results obtained by common methods of determining spectral deficiencies

2. BENEVENTO, L.A.: Movement sensitive binocular neurons and their anatomical connections in the Macaque lateral pulvinar

3. BIANCO, C., MACERATA, A. and MANCINI, P.: Psychophysical evaluation of signal representation

4. de BIE, J. and van der BRINK, G.: A study of fixational eye movements, using small stimulus movements

5. BINGUSHI, K.: Inhibitory effects of false targets in stereopsis

6. BISTI, S. and CARMIGNOTO, G.: Ipsilateral and controlateral visual pathways: different sensitivity to monocular deprivation in kittens

7. BLOCH, H.: Main aspects of visual pursuit in premature infants

8. BLUM, T. and BAUER, R.: Neuromagnetic fields visually evoked by square wave gratings in the upper and lower quadrants

9. CASCO, C.: On the relationship between space and time in the perception of stimuli moving behind a slit

10. CASSON, E.J.: Detection and duration discrimination with long-wavelengths lights

11. DENIEUL, P. and BONNET, C.: Are visual moirés produced by accommodation changes?

12. DEUBEL, H. and ZETZSCHE, C.: Goal-directed saccades in complex visual environment: comparison of pre- and post-saccadic visual information determines the correction saccade

13. DOERFEL, G. and DISTELMAIER, H.: Perception of differences between optically and mechanically presented motion information

14. ELSNER, T. and HAUSKE, G.: Different approaches to the temporal impulse response of the visual system

15. FINDLAY, J. and BALMONT, J.: Amplitude transition functions for small saccades in a target tracking task

16. FISCHER, B. and BLOCH, R.: Conditions of occurrence and reaction times of express-saccades

17. GARY-BOBO, E., FREGNAC, Y. and GRANDJEAN, B.: Spatial contrast and temporal modulation sensitivities in dark reared cats under conditions of binocular and monocular viewing

18. GIULIO, L. and CAMINO, E.: On the time-order criteria in the visual perception

19. GREENLEE, M.W. and SPILLMAN, L.: Patterned spirals enhance the motion after-effect

20. GUSTAFSSON, K.A., PUTAANSUU, J. and BERGSTROEM, S.S.: Information about three-dimensional shape in a square-wave grating projected on backgrounds of different complexity

21. HEITGER, F.: Fourier components of checkerboard and plaid patterns seen in the afterimage

22. JÁÑEZ, L.: Visual grouping without low spatial frequencies

23. KAPOULA, Z. and FINDLAY, J.: Aiming precision and temporal characteristics of saccades

24. KOZACHI, A. and NOGUCHI, K.: The effect of the area of co-existent stimuli on perceived illumination and correlation between perceived illumination and surface lightness

25. KRAUSE, F. and ECKHORN, R.: A new method for the measurement of visual receptive fields

26. LUNDH, B.L. and ARLINGER, S.: Standardization of contrast sensitivity measurements

27. MASIN, S.C.: A psychophysical study of Fuchs phenomenon

28. MIOCHE, L. and PERENIN, M.T.: Contrast sensitivity function in humans visually deprived in early life by bilateral congenital cataracts

29. ORBAN, S.A., van CALENBERGH, F. and MAES, H.: Human velocity coding in central and peripheral visual field

30. PAK, M.A.: Modulation sensitivity functions and the receptive fields of ganglion cells in the pigeon

31. PERRETT, D.I., SMITH, P.A.J., MILNER, A.D. and JEEVES, M.A.: Visual cells selective for type of movement and stimulus form in the temporal cortex of the Macaque monkey

32. de RUYTER van STEVENINCK, R.R. and MASTERBROEK, H.A.K.: Temporal adaptation in a movement sensitive neuron of the Blowfly

33. SADZA, K.J. and de WEERT, Ch. M.M.: Influence of colour and luminance on the Mueller-Lyer illusion

34. SAVARDI, U. and SAVIOLO, N.: The Hermann grid effect in different conditions of illumination

35. SCHMIELAU-LUGMAYR, M.F. and SCHMIELAU, F.: A mu^ti-parametric investigation of simple reaction times to visual stimuli

36. SHECHTER, S. and HOCHSTEIN, S.: Interaction between the processing of the visual bar stimulus dimensions of position, width and contrast

37. van SONDEREN, J.F., de BIE, J. and van den BRINK, G.: The influence of stimulus shape on the fixation point

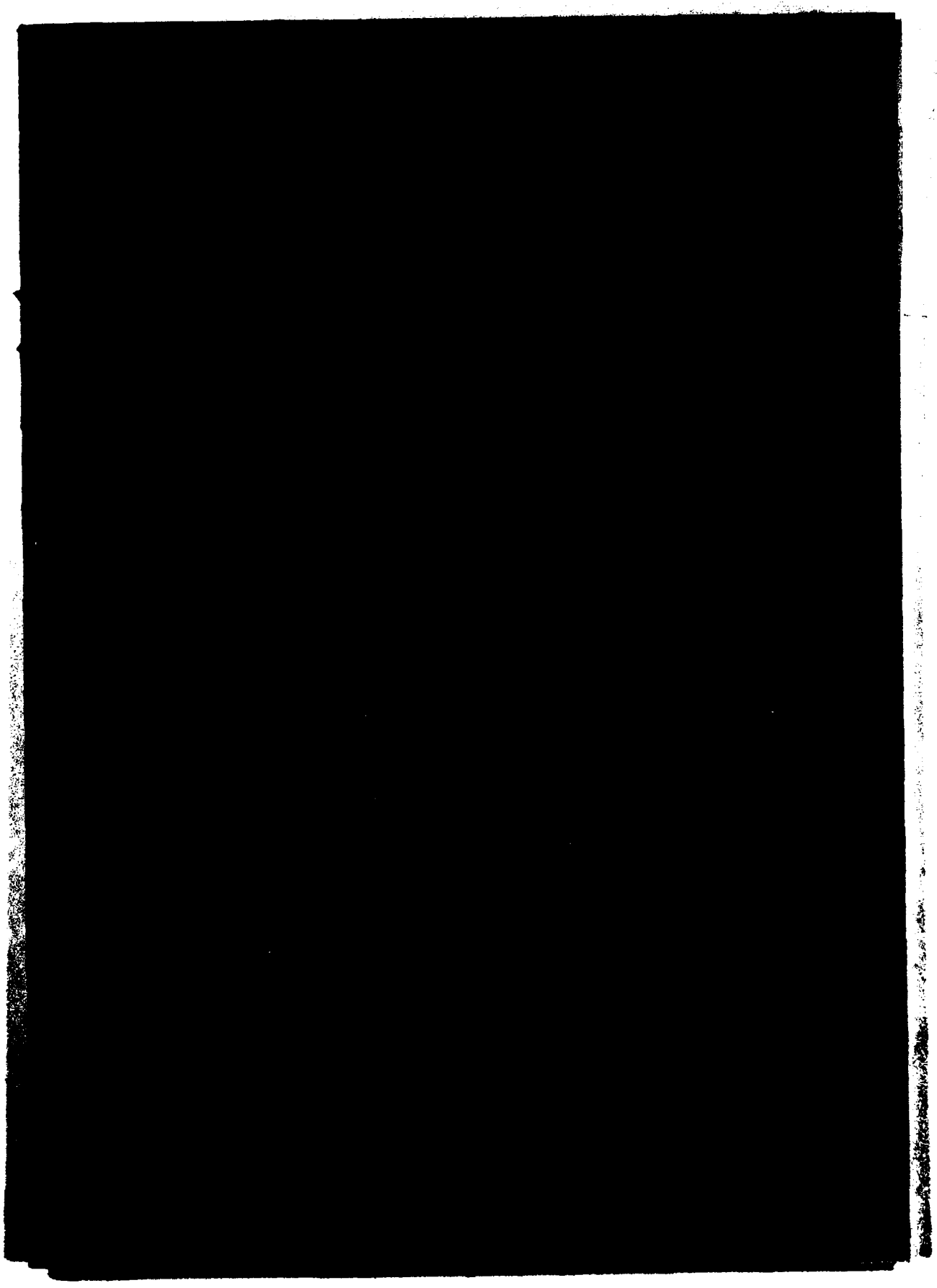
38. STENTON, P. and FRISBY, J.P.: Absolute depth judgements based on vertical disparities

39. STURR, J.F., GASKA, J.P. and CHURCH, K.L.: Evidence for adaptive independence of rods with large fields using field displacement and field additivity

40. VANDENBUSSCHE, E., ORBAN, G.A. and MAES, H.: Are meridional variations in the orientation discrimination performance of the cat line length dependent?

41. VOGELS, R., ORBAN, G.A. and VANDENBUSSCHE, E.: Are meridional variations in human orientation discrimination caused by a decision rule anisotropy?

42. ZAAGMAN, W.H., LENTING, B.P.M. and MASTERBROEK, H.A.K.: Elementary movement detectors



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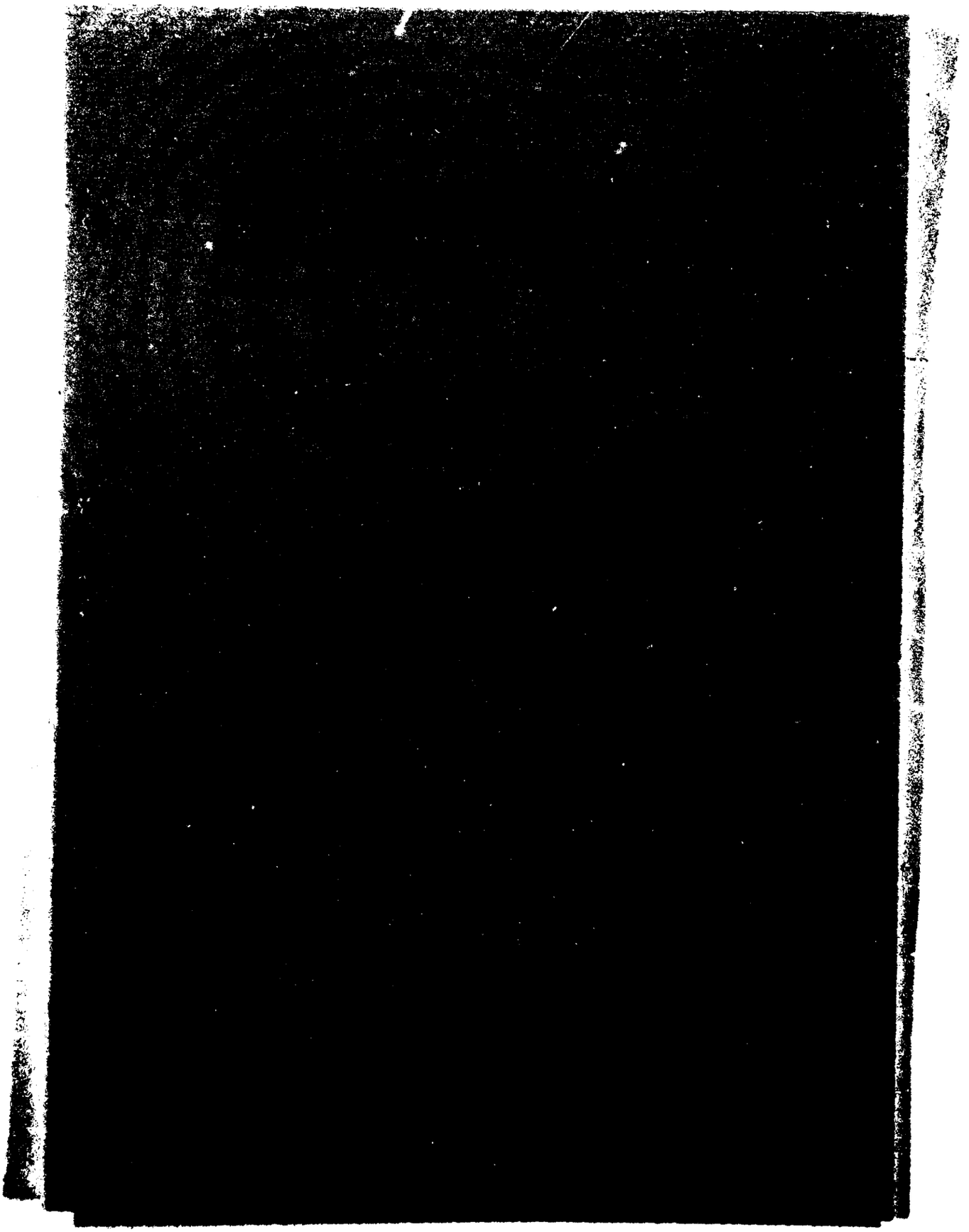

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Sixth European Conference on Visual Perception
Il Ciocco, Castelvecchio Pascoli, Lucca, Italy
28-31 August 1983
Abstracts

Organizer: Adriana Fiorentini
Istituto di Neurofisiologia CNR, Pisa, Italy
Support: US Air Force Office of Scientific Research
Consiglio Nazionale delle Ricerche (CNR)

PROGRAMME

28 August				
18.00	Registration			
21.30	Introductory invited lecture	A2		
29 August				
8.50	Symposium on the Role of Oculomotor Proprioception in Vision	A3		
	Session A		**Session B**	
14.30	Spatial and temporal frequencies 1	A6	Colour 1	A8
16.40	Spatial and temporal frequencies 2	A6	Colour 2	A8
21.30	Business meeting			
30 August				
8.50	Physiology: cortical	A11	Motion perception	A14
11.00	Physiology: cortical and subcortical	A13	Binocular interaction and stereopsis	A15
14.30	Invited lecture	A2		
15.15	Poster session	A28		
17.30	Modeling and visual information processing	A16	Adaptation and colour	A18
31 August				
8.40	Visual development	A19	Visual illusions	A23
10.50	Amblyopia	A21	Peripheral vision	A24
14.30	Miscellany	A26	Miscellany	A26

INVITED LECTURES

INTRODUCTORY INVITED LECTURE

- **What is so odd about seeing?**
  D M MacKay (Department of Communication and Neuroscience, University of Keele, Keele, Staffordshire, England)

In vision research we normally focus close up on specific structures or processes; as a result, some odd features of the phenomenon of seeing tend often to be taken for granted. Some of the latter are highlighted.

The lecture is illustrated by demonstrations which include: (a) the remarkable 'looseness of coupling' observable between what we see and the retinal image; (b) the unity of visual experience despite the multiple fragmentation of visual information at the neuroanatomical level; (c) the extent to which voluntary and evaluative factors can affect what we see; and (d) the ultimate oddity, that all this experience finds itself directly correlated with the activity of some (but not all) neurons in one small corner of the physical world we see.

Some integrative suggestions are explored.

INVITED LECTURE

- **A physics of form perception**
  A P Ginsburg (Aviation Vision Laboratory, Human Engineering Division, Air Force Aerospace Medical Research Laboratories, Wright-Patterson Air Force Base, OH 45433, USA)

One problem in understanding form perception is the lack of a physics of form that can describe relevant information about any object in the same mathematical language as that used to describe visual processes and performance. This has given rise to a large number of competing theories and models of vision, each offering sometimes quite different solutions to common visual problems. Criteria that can be used to evaluate the ability of various models and theories of vision to provide generalized solutions to perception are discussed. A physics of form is described, within the context of linear system analysis and filtering, that is shown to satisfy meaningful criteria. Demonstrations are used to show that the filtering approach is able to quantify form, certain aspects of form generalization, visual illusions, and help explain how a wide range of information contained in complex objects can be extracted by a modest bank of spatial channels. The demonstrations are supported by experimental data that quantify an observer's ability to see complex objects such as letters, faces, and even flying aircraft.

SYMPOSIUM ON THE ROLE OF OCULOMOTOR PROPRIOCEPTION IN VISION

- **The influence of nonretinal components of monocular paralysis on the physiology of mature lateral geniculate nucleus**
  W L Salinger (Psychology Department, University of North Carolina-Greensboro, Greensboro, NC 27412, USA)

After only two weeks of monocular paralysis in the adult cat there is a substantial decrease in encounter rates for X-cells relative to Y-cells in the lateral geniculate nucleus (LGN). This effect has a morphological correlate consisting of a shrinkage in cell body size in regions of the LGN which serve central visual space. Nonretinal factors such as oculomotor proprioception appear to be important in influencing the relative encounter rates for X-cells and Y-cells after monocular paralysis. Thus, combining binocular lid suture with monocular paralysis yields a shift in the relative encounter rates for X-cells and Y-cells despite the elimination of retinally mediated pattern vision. Less direct evidence comes from the finding that multiple intraventricular injections of 6-hydroxydopamine block the shift in encounter rates usually produced by monocular paralysis. Finally, when a barbiturate anaesthesia state is induced by intravenous injection during recording, there is an immediate restoration of the normal encounter rates for X-cells and Y-cells. This effect may be mediated by the mesencephalic reticular formation (MRF) since local injections of barbiturate directly into the MRF yield the same immediate result.

- **Extraocular muscle proprioceptive signals reach the vestibular eye-movement control system**
  J A Ashton, A Boddy, I M L Donaldson (Department of Zoology, The University, Hull HU6 7RX, England)

Our recent experiments suggest that proprioceptive signals from extrinsic ocular muscles (EOM) play a part in the control of eye movements through their effects on the vestibular nuclei (VN). In the giant toad (*Bufo marinus*), an amphibian whose eye movements are limited to compensatory movements in response to head or body displacement, some units in the VN have been found to be excited by passive eye movement, in the decerebrate, paralysed, animal. VN cells were identified by their short-latency responses to electrical stimulation of the ipsilateral vestibular nerve. Control experiments eliminated visual, auditory, and cutaneous sources for the signal from passive eye movement, and electrical stimulation of the intraorbital part of the fourth cranial (trochlear) nerves provided evidence that the EOM are the source of the afferent signal. VN cells project mono- and polysynaptically to the oculomotor nuclei (OMN) and so EOM afferent effects on the vestibular input to OMN would be able to influence the control of eye movement. We have some evidence that EOM signals can modify the excitability of OMN units as tested by vestibular input. The significance of these results is discussed.

- **Units in cat primary visual cortex respond preferentially to particular directions of passive eye movement**
  J A Ashton, A Boddy, I M L Donaldson (Department of Zoology, The University, Hull HU6 7RX, England)

Extracellular recordings were made from single units in the right visual cortex (area 17) of cats anaesthetized with chloralose and paralysed with gallamine, and responses to passive movement of the right eye were examined. The eye was moved, in the dark, by an electromagnetic device acting on a stalk carried by an opaque suction contact lens applied to the globe. The whole eye-mover rotated about the axis of the stalk to produce eye movement along any desired radius. To test for directional preference, poststimulus time histograms were constructed in groups of four, in which responses to movement in at least two orthogonal directions were tested. Of 32 units which responded to passive eye movement, 25 showed differences which were considered significant between at least two orthogonal directions of movement. In most of these units the relative directional preference was stable over time even though the absolute size of the responses might vary. The significance of these results is discussed.

- **Accuracy and timing of information in a visual localization task requiring the use of nonretinal eye-position information**

A Skavenski (Northeastern University, Boston, MA 02115, USA)

In attempting to account for accurate visual space perception when organisms move their eyes, it has been proposed that neural correlates of eye position from nonretinal sources are used to compensate for shifts of the retinal image, but this is challenged by experiments which demonstrate failures of the nonretinal eye-position signals around the time of saccades in judgements of the visual direction of one visible target with respect to another. We used a magnetic-field search-coil technique to detect when subjects made a 5-8 deg arc horizontal saccade in total darkness and trigger illumination of a small target for 1 ms either before, during, or after the saccade. Mean positions of the ballistic pointing responses were about 20 min arc from the target and varied only slightly with the time of target exposure relative to the saccade. Since the background and the subject's body were never visible, these localizations required the use of a nonretinal eye-position signal, and that signal appears very closely locked both in magnitude and timing to the subjects' eye movements. Variation of target luminance from threshold to 5 log units above—a range that produced a 200 ms difference in reaction time—had no effect on pointing accuracy. This indicates that the localization mechanism employs a retinal image position correlate whose latency is invariant with image luminance. Thus the visual and eye-position correlates are sufficiently concordant with the events they represent that a mechanism which combines them could account for good space perception. Suggestions about how the brain might do this are drawn from our ongoing neurophysiological experiments in monkey parietal cortex.

- **Role of extraocular proprioception in visually guided behaviour of cats**

A Fiorentini, L Maffei (*Istituto di Neurofisiologia* CNR, 56100 Pisa, Italy)

Adult cats were trained in various visual tasks and then tested after unilateral section of the ophthalmic branch of the fifth cranial nerve. In cats trained to jump to a target at various possible locations in the visual field the postsurgical jumping direction was found to deviate systematically from target in a direction ipsiverse to the side of the section, both for jumps guided binocularly and for jumps guided monocularly with either eye. In cats trained to discriminate differences in depth by a jumping stand technique the binocular depth threshold is typically 3-4 times larger after than before surgery. Neither behavioural visual acuity, nor visual field amplitude (as determined by visual perimetry) were affected by proprioceptive unilateral deafferentation. No sign of strabismus was observed in the operated animals, and the eye and head movements triggered by a moving stimulus in partially restrained cats were not grossly different after surgery from those observed before surgery. These findings indicate that extraocular proprioception plays a role in the visually guided behaviour of cat.

- **Efference to and afference from extraocular muscles are critical to development in visual guidance in cats**

A Hein (Department of Psychology, Massachusetts Institute of Technology, Cambridge, MA 02139, USA)

Oculomotor contributions to acquisition of guided behaviour were examined in two series of studies. In one the eye was surgically immobilized. Dark-reared kittens failed to develop guidance when postoperative exposure in light was provided. Kittens that had acquired those behaviours during preoperative exposure in light did not lose them after surgical immobilization. Thus visually elicited eye movements are crucial to acquisition of visually guided behaviours but not to their maintenance once developed.

In the second series, afference from extraocular muscles was surgically interrupted. Dark-reared kittens failed to acquire guided behaviour during subsequent exposure in light. Light-reared kittens whose extraocular muscles were deafferented retained their previously acquired capacity for guidance. This set of results parallels those from the studies of eye immobilization: both visually-elicited eye movement and proprioception from the extraocular muscles are essential to acquisition of visually guided behaviours but may be dispensed with once this development has taken place. Other studies of kittens with paralyzed or deafferented eye muscles indicate that under certain exposure conditions information provided by an intact fellow eye can enable the operated eye to acquire the capacity to mediate guided behaviours.

- **Roles of sensory signals from extraocular muscles in developmental processes of visual cortical cells properties**

P Buisseret (Laboratoire de Neurophysiologie, Collège de France, 75231 Paris, France)

Visual deprivation during the critical period (dark-rearing, contours of a single orientation, strabismus, monocular exposure) induces abnormal properties of cortical neurons (without orientation selectivity, tuned towards the experienced orientation, monocularly activated). It has been suggested that these vision-dependent modifications are achieved by a synergy between vision and nonretinal factors. It is asserted that these factors include sensory signals from extraocular muscles. This claim is based on the following results: (i) The post-exposure restoration of the orientation selectivity, observed in intact dark-reared kittens did not happen if the extraocular muscles had been deafferented (E Gary-Bobo). (ii) Monocular activation observed after strabismus or monocular deprivation did not occur in similarly deafferented kittens (W Singer). (iii) After a normal visual exposure, almost all cortical neurons coded about the same orientation as when the eye movements of the kittens had been restricted to only one direction during the exposure time, by removing 4 out of the 6 extraocular muscles (E Gary-Bobo, C Milleret). (iv) A decrease in binocularity was observed either in normally or dark-reared kittens after bilateral eye-muscle deafferentation. After dark-rearing a monocular visual exposure had, when associated with an unilateral deafferentation, a less pronounced effect if the exposed eye was the deafferented one (Y Fregnac, Y Trotter). These experiments show that sensory signals from extraocular muscles may have different roles during development of the visual cortex. First, a gating role in orientation-selectivity development (i), and in ocular dominance plasticity (ii), when deafferentation is bilateral. Second, more subtle interactions as in (iii) and (iv) when deafferentation is unilateral or bilateral but partial.

CONTRIBUTED PAPERS

SPATIAL AND TEMPORAL FREQUENCIES

- **Perceived contrast of pulse amplitude modulated gratings**
  G Nyman, P Laurinen, T Radil (Department of Psychology, University of Helsinki, Helsinki, Finland)

In the study of temporal dynamics of human vision, flickering stimulus fields have been used in which the duty cycle of the temporal modulation waveform could be varied. Related methods can be applied to the study of spatial vision with properly modulated stimuli. We used temporally and/or spatially pulse amplitude modulated (PAM) gratings with sinusoidal waveforms to study the effect of modulation on perceived grating contrast. The subject matched the contrast of a PAM sinusoidal grating with that of a steady and continuous grating. Three spatial frequencies, 2, 4, and 8 cycles deg^{-1}, were used. The results suggest that within a narrow range of pulse-to-cycle fractions the effects of spatial and temporal pulse amplitude modulation on the perceived contrast of the gratings are equal. The reciprocal effects of the two forms of modulation suggest that a law similar to the Talbot-plateau law for flickering fields holds for both spatial and temporal domains.

- **Spatial integration of raster-sampled gratings in human vision**
  P Laurinen, G Nyman (Department of Psychology, University of Helsinki, Helsinki, Finland)

The capacity of spatial-frequency-selective mechanisms to recognize spatial patterns can be studied by using spatially sampled stimuli in which the sampling rate is made adjustable. We used sinusoidal gratings to study the effect of sampling rate on the appearance of the gratings, and related related the results to the Shannon-Whittaker theorem of sampling. Eight different spatial frequencies (25-12 cycles deg^{-1}) and four grating sizes were used. The ability of the visual system to 'reconstruct' percentually the waveforms of the sampled gratings is relatively poor for low spatial frequencies and for gratings in which only a few spatial cycles are visible in the stimulus window. For the spatial frequencies studied the necessary sampling rate for recognizing the grating waveform varied from 10 to 2 times the Nyquist rate of the grating. By extrapolating to the Nyquist limit a theoretical resolution value of about 70/80 cycles deg^{-1} was obtained. 'Psychophysical undersampling' effects occur in the sampled grating before the Nyquist limit of sampling is reached. The perceived properties of such undersampling effects cannot be predicted from the consideration of the spectrum of the sampled signal.

- **Spatiotemporal tuning of channels from detection/discrimination experiments**
  P Thompson (Department of Psychology, University of York, York, England)

Evidence is mounting that the perceived rate of movement of a sine-wave grating may be coded by as few as two broadly tuned temporal-frequency channels. Rather little is known of the spatial-frequency tuning of these channels beyond the observation that at low temporal frequencies the tuning is narrow and at high temporal frequencies it is broad.

The discriminability of moving gratings which differ in their spatial frequencies, but not in their temporal frequencies, was used to estimate the minimum number of channels required to encode spatial-frequency information at each of several temporal frequencies. Further experiments were performed to examine the discriminability of gratings at their detection thresholds which differ in spatial and temporal frequency but which have the same velocity. The results are considered within the framework of the model of velocity perception presented at the 5th ECVP (*Abstract in Perception* **11**(1) A5).

- **Temporal-frequency channels in vision revealed by noise masking**
  D G Pelli¶, A B Watson# (Physiological Laboratory, Cambridge University, Cambridge, England)

In 1940 Fletcher showed that a listener's threshold for a tone is affected only by noise frequencies close to the frequency of the tone. This is a powerful method for revealing frequency selective mechanisms, or *channels*, in any sense modality. Analogous techniques have revealed visual

spatial-frequency channels and temporal-frequency channels. However, it has recently been shown that these data must be interpreted with care because observers can learn to listen off-frequency and look off-frequency. Pelli showed that off-frequency looking can be controlled by using high-pass or low-pass noise.

Experiments in which temporally high-pass and low-pass noises were used revealed three broadly tuned temporal-frequency channels (with peaks at 0, 6, and 12 Hz) at a spatial frequency of 0.25 cycle deg^{-1}.

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- **A comparison of reaction-time and temporal-order-judgement estimates of latency to sinusoidal gratings**

M Barr (Department of Experimental Psychology, University of Oxford, Oxford, England)

It is well established that the mechanisms that respond to low spatial frequencies have 'brisker' temporal properties than mechanisms sensitive to high spatial frequencies. This does not necessarily imply that there is a temporal phase difference in their onset responses, although this appears to be indicated by reaction-time studies showing latencies to high-spatial-frequency stimuli delayed by up to 100 ms with respect to low-spatial-frequency stimuli of equal contrast. A temporal-order-judgement method was employed to discover if the perceptual onsets of simultaneously presented high-spatial-frequency and low-spatial-frequency gratings appeared asynchronous. The point of subjective simultaneity was found to be approximately zero under several conditions, implying either that there is some form of compensation for sensory-latency differences, or that the reaction-time differences are due to a spatial-frequency-dependent or an intensity-dependent post perceptual delay.

- **A multiple-channel model explains the detection of low-frequency complex gratings**

W Jaschinski (Institut für Arbeitsphysiologie Ardeystraße 67, 46 Dortmund, FRG)

A space-domain version of the multiple-channel model that was proposed in 1974 by MacLeod and Rosenfeld to describe the sensitivity of the visual system to complex gratings has been modified in detail, to include both symmetric and antisymmetric receptive fields. It is shown that the model predicts correctly the contrast sensitivity to square-wave gratings, square-wave with missing fundamental, sawtooth-wave, and trapezoidal-wave gratings of different ramp widths. It gives a physiologically reasonable explanation of the detection of contrast gradients, and accounts for the detection of gratings with identical amplitude spectra but different phase spectra. A major advantage of the model is that it can account for sensitivity at low and at high spatial frequencies.

- **Contrast sensitivity used in predicting the ability to detect complex targets**

A Ginsburg (Aviation Vision Laboratory, AFAMRL/HEA, Wright-Patterson Air Force Base, OH 45433, USA)

It is not always possible to predict on the basis of visual acuity how well targets will be seen by subjects in most situations, whereas contrast sensitivity function (CSF) can be used to predict an observer's ability to see virtually all targets, including spatially complex letters and aircraft silhouettes. Earlier studies were limited to static test conditions and simple tasks.

Two recent studies are reported which show the power of contrast sensitivity when used as a basis for predicting complex visual performance. The first study showed predictable differences for the discrimination of two road signs, X and T, during a simulated driving task for two different age groups. A group with a mean age of 67.1 years required 24% closer distance to discriminate the approaching road signs than a younger group with a mean age of 25.1 years. Significant correlations were found between contrast sensitivity and discrimination distance but not visual acuity. The second study showed that a pilots' ability to detect a small semiisolated target during a simulated aircraft landing could be better predicted on the basis of contrast sensitivity than on the basis of visual acuity. Contrast sensitivity, not visual acuity, of eleven instructor pilots showed the highest significant correlation to slant detection range.

- **Modeling Bloch's law for contrast**
  A Gorea, C W Tyler (Smith-Kettlewell Institute of Visual Sciences, 2200 Webster Street, San Francisco, CA 94115, USA)

A linear analytical approach accounting for the temporal integration of contrast as a function of spatial frequency is presented. On the assumption that the temporal impulse response of the visual system entirely determines its full integration time limits, four related models have been developed all of which take into account probabilistic time integration characteristics. Contrast sensitivity has been made directly dependent on the output of (i) one infinite sign-rectifying integrator; (ii) two infinite sign-selective integrators whose outputs are probabilistically combined; (iii) a version of (i) where the outputs of many time-limited rectifying integrators are probabilistically summed over an infinite time span; and (iv) a similarly time-limited version of (ii).

By using both biphasic ('transient') and monophasic ('sustained') impulse responses model (iii) best fits contrast sensitivity data obtained with low and with high spatial frequencies, respectively. The striking differences in the shapes of the contrast threshold versus time curves for low and high spatial frequencies are entirely explained by the statistical interactions between the probabilistic summation operator and the degree of inhibition in the impulse response. The critical duration predicted by any of these models and verified by the data is of about 30 ms and varies by only 10 ms across spatial frequency. These results are in strong contrast with previous estimates of critical durations for grating stimuli.

- **Visual sensitivities to two-dimensional frequency differences**
  B Treutwein, I Rentschler, T Caelli (Institut für medizinische Psychologie der Universität München, München, FRG, and University of Alberta, Edmonton, Canada)

In a previous study nondiscrimination ranges of about ½-octave radial frequency width and 10° orientation width have been determined in the two-dimensional spatial-frequency domain. The technique used was to match two gratings displayed alternately for 120 ms: one grating was fixed in spatial frequency and orientation while the other could be varied about these values in one or the other dimension. It is tempting to convert these data into 'frequency-discrimination ellipses' just as sensitivities to colour differences are conventionally characterized by McAdam ellipses. The difficulty is that the data have been obtained from independent matches along the radial frequency or orientation dimensions. However, Daugman demonstrated that two-dimensional spatial-frequency channels cannot be conceptualized as the product of a frequency-tuning curve times an orientation-tuning cruve or, in other words, frequency and orientation are nonseparable variables. We have developed, therefore, a computer-aided technique for simultaneously varying frequency and orientation while measuring discrimination sensitivities. The resulting nondiscrimination areas are analyzed as to their deviation from elliptic shape. This allows for comparison with Daugman's results from masking experiments. Implications of the data for deriving a line-element theory of spatial vision are discussed.

COLOUR

- **Testing colour-opponent theory in the retina**
  P Gouras, H Eggers (Department of Ophthalmology, Columbia University, New York NY 10032, USA)

Pure-hue contrast stimuli have been used to examine the responses of single retinal ganglion cells of primates. Only one subset of these cells, those excited by the short-wave sensitive cones and inhibited by the other cones, ie the blue-on/yellow-off variety, can distinguish white/yellow contrast. This implies that the paired opponent channels of Hering's colour-vision theory do not exist in the retinogeniculate pathway.

- **Luminance-response curves and spectral selectivity of cells in the parvocellular layers of the macaque lateral geniculate nucleus**
  B B Lee, A Valberg, D A Tigwell (Max-Planck Institut für biophysikalische Chemie, D-3400 Göttingen, FRG)

Cells in parvocellular layers of the lateral geniculate nucleus of macaque are wavelength-selective. Their responses were studied with visual stimuli briefly replacing a white adaptation field. With stimuli of different wavelengths, spectrally narrow-band cells have chromatic thresholds about 2 log

units below the luminance of the adaptation field (luminance ratio 10^{-2}). Maximum responses occur at a luminance ratio of 10^{-1}, and further increases in luminance result in weaker responses. Spectrally wide-band cells have chromatic thresholds at a luminance ratio of 10^{-1} and their responses reach a maximum at about 1 to 1.5 log units above threshold; further increases in intensity cause little change in response.

These responses can be described by linear interaction of opponent-cone mechanisms, each following a saturating hyperbolic function. Such linear interaction has previously been shown to account for responses to wavelength mixtures presented on a background. The simulation can predict how cells respond to stimuli varying in intensity and saturation. This quantitative description may make it easier to relate neurophysiological data to colour-vision behaviour.

- **Fourier interferometric measurement of the scotopic and photopic spectral sensitivity of humans**

  P Rüdiger (Zoologisches Institut der Universität, Luisenstraße 14, 8 München 2, FRG)

Use of the Fourier interferometric stimulation technique leads to a quick and precise determination of the spectral sensitivity of humans by frequency analysis of the ERG-response of the eye to Fourier interferometric stimulus. In addition to the scotopic sensitivity we were able to determine the photopic sensitivity. The corresponding curves are definitely wider than the scotopic ones. Depending on light intensity they either shift to blue or to the red region of the spectrum. The technique gives markedly different results for spectral sensitivities of colour-abnormal subjects, compared to normal ones. Under specific conditions (chromatic adaptation) the single-peak photopic sensitivity changes into a multiple-peak curve. The position of the peaks seems to imply a separation of the blue-green-red cone mechanism. The possibility of applying this method in clinical diagnostics is discussed.

- **Contributions of chromatic increment threshold (π-) mechanisms to two spatiotemporal filters in human vision**

  I E Holliday, K H Ruddock (Departments of Physics and Pure and Applied Biology, Imperial College, London SW7 2BZ, England)

Achromatic threshold detection studies with simple moving stimuli presented upon spatiotemporally modulated background fields reveal two classes of spatiotemporal (ST) filter (Holliday and Ruddock, 5th ECVP; Abstract in *Perception* **11**(1) A20). The chromatic mechanisms subsuming the achromatic responses were investigated by means of the two-colour increment threshold technique of W S Stiles. It has already been shown that for the ST1 filter π1 exhibits a larger 'receptive field' than π4 or π5 (Barbur and Ruddock 1980 *Biological Cybernetics* **37** 77-105). For ST2 the blue-sensitive response (π1) again differs from the red- and green-sensitive mechanisms in that it gives a lower temporal-frequency response. The spatial response is similar for all three chromatic mechanisms. It is also shown that for the ST2 filter, which is selective for transient stimuli, the red-sensitive mechanism is not described by the π5 response mechanism.

- **Nonlinear relationship between large and small chromaticness differences of an equiluminous colour series**

  K Richter (Bundesanstalt für Materialprüfung (BAM), Unter den Eichen 87, D-1000 Berlin 45, FRG)

From a plot in the CIE chromaticity diagram of MacAdam ellipses (representing small colour differences) and data of the OSA colour system (representing large colour differences) only a *nonlinear relationship* between the two could be assumed.

Relative scaling in chromaticness of a colour series between saturated red and green and just noticeable colour differences in that series were determined by six observers. The large chromaticness differences were better represented in the colour space LABHNU2 than in the colour spaces CIELAB and CIELUV. The just noticeable chromaticness differences near the D65 chromaticity of the surround were greater by a factor of 3 than the differences for the saturated red and green colours. An equation connecting the two results and conclusions are presented.

- **Screening for colour blindness by making use of optokinetic nystagmus**
  G Mather, P Cavanagh, S Anstis (York University, York, England, and University of Montreal, Montreal, Canada)

Red/green luminosity ratios were determined in normal and colour-blind subjects by a new method. A special coloured grating of red and green bars appeared to move to the right (or left) when the red bars were lighter (or darker) than the green bars. As the red/green ratio passed through equiluminance, the direction of apparent movement reversed. Optokinetic nystagmus elicited by the stimulus could be measured photoelectrically, or by directly watching the subject's eyes. When the red/green ratio reached the equiluminance point both the reported apparent movement and the optokinetic nystagmus reversed in direction. Protans needed more red than normals to reach equiluminance, and deutans needed more green. The method might be applied to nonverbal subjects such as infants and animals.

- **Hue discrimination by a rhesus with chronic unilateral induced tritanopia**
  H G Sperling, A A Wright (University of Texas Health Science Center at Houston, Graduate School of Biomedical Sciences, Sensory Sciences Center and Department of Ophthalmology, Houston, TX, USA)

Ten years after a rhesus's right eye was rendered tritanopic by a series of blue-light exposures in a behavioural setting the monkey was trained by operant procedures to move a lever in the direction of the odd colour of three 0.75 deg maxwellian spots surrounded by a 10 deg, 3000 troland achromatic field. Average hue discrimination across the spectrum in the eye exposed to the light very closely resembles the human tritanopic data of W D Wright, while the monkey's unexposed eye reveals normal spectral sensitivity and hue discrimination. These results are discussed in the context of models of colour-receptor distribution and interaction.

- **Visual neurons respond differently to light from fluorescent tubes and incandescent lamps**
  U Th Eysel, U Burandt (Institut für Physiologie der Universität Essen, D-4300 Essen, FRG)

The responses of single neurons in the optic tract, the lateral geniculate nucleus and the optic radiation to natural and artificial light have been recorded from anaesthetized cats. The animals viewed a 50 deg stimulus field illuminated by incandescent lamps, fluorescent tubes, and daylight.

Under standardised conditions the impulse rates and patterns of response to incandescent lamp light were rather similar to the responses to natural light. When stimulated with fluorescent tube light on-centre and off-centre neurons displayed increased and highly phase-locked responses. This resulted in very uneven impulse probability distributions in poststimulus time histograms and multimodal interval histograms. Some optic-tract neurons had not even reached their critical flicker-fusion frequency (at 100 Hz) with fluorescent tube light of 150 cd m^{-2}. A number of off-centre neurons was excited by large field fluorescent tube light illumination while being inhibited by incandescent lamp light under the same conditions. Neither increasing the mains frequency to 60 Hz nor reducing the mean luminance to 38 cd m^{-2} could abolish the characteristic flicker responses to fluorescent tube light.

The results show a different biological effect of natural and different kinds of artificial light on first-order and second-order central visual neurons of the cat in terms of impulse rates and temporal response properties.

- **Does the visual system perform global or local spectrum analysis of luminance and colour patterns?**
  R Röhler, W Schill, E Perizonius, H Geiger (Institut für medizinische Optik der Universität München, München, FRG)

The main purpose of our experiments was to examine, whether the human visual system has mechanisms which transfer information about the spatial-frequency spectrum of only a limited area of the visual field. If such mechanisms exist, then the contrast threshold should depend on the distance between the adaptation and test area.

We used a test field which consisted of four rectangular subfields; in one of these were displayed moving sinusoidally-modulated luminance or colour gratings of different spatial frequencies. Our results show that the influence of the adaptation grating on the contrast threshold of the test grating decreases with increasing distance between them. This is valid for both luminance and colour, and provides evidence for the existence of a local spectral-analysis mechanism in the visual system.

- **Hue shifts in colour gratings depend on spatial frequency**
  C Fach, L Spillmann (Neurologische Klinik mit Abteilung für Neurophysiologie, Hansastraße 9, D-7800 Freiburg i. Br., FRG)

Colour induction is usually investigated with a large inducing field surrounding a small test field, but little is known about the reciprocal interaction between such stimuli. To measure these interactions we used square-wave colour gratings, made up of all combinations of the following Munsell papers: 5B, 5G, 5Y, 5R, and N6. All were equal in lightness and saturation (Munsell 6/6). The gratings were surrounded by a neutral field (N6) and illuminated by CIE source C. The luminance was 56.5 cd m^{-2}. Spatial frequency was varied from 1 to 15 cycles deg^{-1} equivalent to single stripe widths of 30 min to 1.8 min arc. Subjects with normal colour vision and acuity matched the hues of the grating with Munsell colour swatches.

At 15 cycles deg^{-1} hue shifts were most prominent. Blue shifted towards red or yellow when combined with these colours (assimilation), but remained relatively unchanged when combined with green. Green showed assimilation with all colours, as did red. Yellow shifted only a little, irrespective of the second grating colour. The hue shift lessened with decreasing spatial frequency and disappeared at about 5 cycles deg^{-1}. With coarser gratings assimilation changed to contrast. In gratings in which grey stripes were paired with coloured ones no hue shift was observed. These results are attributed to the receptive-field organization of double-opponent cells. Chromatic aberration, macular pigment, and small-field tritanopia seem to play minor roles.

PHYSIOLOGY: CORTICAL

- **Different measures of visual acuity in area 17 cells**
  H C Nothdurft (Department of Neurobiology, Max-Planck-Institut für biophysikalische Chemie, D-3400 Göttingen, FRG)

Response patterns from cells in cat visual cortex to texture stimuli have been analyzed for the representation of stimulus details. One common measure of visual acuity in single neurons is the *spatial resolution* threshold describing the minimal spacing for which separate stimuli evoke discrete responses. In geniculate cells, this threshold correlates with the size of the excitatory receptive field (Wässle and Creutzfeldt, 1973 *Journal of Neurophysiology* **36** 13-27); in simple cells in area 17 it does not (Nothdurft, 1976 *Biological Cybernetics* **24** 153-163). Our experiments revealed further ways of encoding spatial details in a response. On the one hand, complex cells could discriminate line orientation of textured grids far below their spatial-resolution limit. This implies that *orientation discrimination* might be a more appropriate measure for visual acuity with these cells than spatial resolution. On the other hand, simple cells responded to differences in mean luminance of textured patterns only when structures were very fine. Thus, the threshold for *spatial integration or fusion* of structural details is another manifestation of visual acuity in single neurons, which, by referring to unresponsiveness rather than responsiveness of a cell, would be functionally meaningful only in cooperation with the firing of other cells.

- **Monocular receptive-field structure of binocular simple cells in cat striate cortex: a comparison of the two eyes**
  D A Tigwell, B B Lee (Max-Planck Institut für biophysikalische Chemie, D-3400 Göttingen, FRG)

The receptive-field structure of simple cells determined with sine-wave gratings or moving bars and edges may be used to infer the afferent input from on-centre and off-centre cells. The majority of simple cells fall into two groups in phase response to moving sine-wave gratings. These correspond in response phase to on-centre and off-centre cells at retinal and geniculate levels, implying that most simple cells receive input from on-centre or off-centre afferents but not both.

Phase behaviour for each eye was evaluated. Cells responding in phase with a luminance maximum, when tested through one eye, showed similar behaviour for the other, suggesting that such a cell receives predominantly on-centre input from each eye. A similar result was found for cells responding to a luminance minimum in the grating, therefore putatively receiving off-centre input from each eye. For those cells with more complex phase behaviour, suggesting mixed on-centre and off-centre input, identical phase behaviour for the two eyes was found.

Analysis of responses of the cells to moving bars and edges supported the conclusion that receptive-field structure, and by implication excitatory input, is very similar for the two eyes, suggesting a high degree of specificity of afferent connectivity.

- **On the distinctness of simple and complex cells in the striate cortex of the cat**
  A F Dean, D J Tolhurst (Physiological Laboratory, Cambridge University, Cambridge CB2 3EG, England)

The behaviour of cortical neurons was examined in response to moving sinusoidal gratings and to flashed bright and dark lines. The responses were quantitatively summarized by two indices: (i) 'spatial summation ratio' (SSR), showing the degree of spatial summation within the receptive field; (ii) 'relative modulation', a measure of the degree of modulation in the response to a moving grating. For neurons with spatially separated regions of 'on' and/or 'off' response in their receptive fields, the ratio of the width of one region to the width of the bars in the grating of optimal spatial frequency was determined. This defines the SSR. For 90% of these neurons values were close to 1, indicating linear spatial summation. However, receptive field regions of some neurons exceeded the width of the bar of the optimal grating by a factor greater than 2. The values obtained were continuously distributed. For all neurons the waveform of the response to a moving grating of optimal spatial frequency was examined. The relative modulation was continuously distributed between low values typical of complex cells and high values typical of simple cells. Contrary to expectation, neither response modulation nor degree of spatial summation is alone capable of reliably distinguishing simple from complex cells.

- **Correlation between space and time in areas 17 and 18 of cat**
  S Bisti, G Carmignoto, L Galli, L Maffei, M Pirchio (Istituto di Neurofisiologia del CNR, Pisa, Italy)

To investigate the correlation between spatial and temporal properties in single cells of areas 17 and 18 of cat we recorded responses of single neurons as a function of various parameters (contrast, spatial frequency, direction of drift etc) of a variety of visual stimuli (drifting gratings, contrast reversing gratings, visual noise). It turns out that in area 17 the spatial and temporal tuning curves of single neurons are invariant with respect to the type of the stimulus (drifting gratings, etc). Moreover, the temporal (spatial) tuning curve is largely independent of the spatial (temporal) frequency of the stimulus. In area 18 the temporal and spatial tuning curves of single cells strongly depend on the kind of stimulus used. A possible role of these two cortical areas of the cat in the processing of visual information is discussed.

- **Electrophysiological responses to vernier offset in human visual cortex**
  D M Levi, R E Manny, S A Klein, S B Steinman (University of Houston College of Optometry, Houston, TX, USA)

Human observers can discriminate vernier offsets which are smaller than a single cone diameter. We recorded the cortical evoked potentials (EP) of human observers to the appearance/disappearance of vernier offsets. The stimulus consisted of a horizontal line composed of three segments. The vertical vernier offsets were produced by displacing either the middle segment or the two lateral segments up or down, with no change in luminance. The responses were characterised primarily by a positive deflection at about 150 ms after the appearance of the stimulus. The total number of offsets was varied by adding extra line segments or additional horizontal lines. Robust and reliable cortical responses were elicited to vernier offsets as small as 16 s of arc. The peak-to-trough amplitude varied systematically with the magnitude of the vernier offset. Extrapolation of the EP amplitude to the noise level provided an estimate of vernier thresholds which were consistent with the observers' psychophysical thresholds. These cortical EP to vernier offset do *not* represent a pure motion (displacement) response, but appear to represent the cortical response to the fine relative position cue in the vernier offset. The EP response to vernier stimuli may lead to an understanding of the physiological substrate for hyperacuity.

PHYSIOLOGY: CORTICAL AND SUBCORTICAL

- **Spatial and temporal information transmitted through the corpus callosum**
  L Maffei, S Bisti, N Berardi, L Galli (Istituto di Neurofisiologia del CNR, Pisa, Italy)

We investigated the spatiotemporal characteristics of the information transmitted through the corpus callosum (CC) in adult cats. Visual evoked potentials (VEP) in response to sinusoidal gratings alternating in phase were recorded by means of an electrode inserted into the CC. The resulting modulation transfer functions both in the temporal and spatial domain were found to be very similar to those obtained with VEPs recorded with external electrodes. We then prepared a number of split-chiasm cats and recorded VEPs and single-cell activities with an electrode inserted into area 17, near the projection of the area centralis, and compared the contralateral with the ipsilateral visual input. We found no striking differences between the modulation transfer functions in the space domain of the two inputs. In the minority of single cells in which the contralateral input could be found, its spatial properties seemed to be similar to those of the direct input, while its temporal properties seemed to be different.

- **Visual cells sensitive to face orientation and direction of eye gaze in the macaque monkey**
  D I Perrett, P A J Smith, D Milner, M A Jeeves (Psychological Laboratory, University of St Andrews, St Andrews, Fife, KY16 9JU, Scotland)

The direction of eye gaze and orientation of the face are important social signals for man and the macaque monkey. We studied the effects of these signals in a region of the temporal cortex where cells have been found to be responsive to the sight of faces. Different populations of cells were found to become active as the head was rotated horizontally to profile, or was tilted vertically to face the floor or ceiling. The same populations of cells, however, remained active as stimuli were rotated isomorphically or were changed in size/distance. Fifteen cells responded only when the face or eyes were directed at the monkey; twenty cells behaved in an opposite way, responding only when the face or eyes were directed away from the monkey. Experiments presenting the eyes or the rest of the face alone revealed independent sensitivity for face orientation and gaze direction. Results suggest that the recognition of one type of object may proceed via the independent high-level analysis of several restricted views of the object (viewer-centred descriptions), rather than the direct access of visual information to a single canonical (object-centred) description.

- **Foveofugal organization of direction selectivity in the second visual system of the cat**
  J P Rauschecker (Max-Planck-Institut für biologische Kybernetik, 7400 Tübingen, FRG)

Signals from the retina reach the cortex over two distinct pathways: the geniculo-striate pathway, and the colliculo-extrastriate pathway which is relayed in the lateralis posterior nucleus of thalamus. The organization of direction selectivity in this second visual system was studied.

Single units were recorded from the lateralis posterior nucleus and from both banks of the lateral suprasylvian cortex (PMLS and PLLS) in the cat. The selectivity of these neurons for the direction of a moving light spot was tested. It was found that the optimal direction very often contained a vector component pointing away from the area centralis; the direction preference of a cell thus often depended on its receptive-field location. This was true both at the thalamic and at the cortical level.

Many of these neurons also show marked binocular facilitation, direction preference being the same for both eyes. Together with the above property of foveofugal organization of direction selectivity this would make the system optimally suited for the detection of approaching objects and their avoidance or capture.

- **Lack of binocularity in area 19 of Siamese cats**
  F Lepore, S Bédard, M Di Stefano#, C A Marzi#, S Molotchnikoff (Psychologie, Université de Montréal, Montreal, Canada; #Istituto di Fisiologia, Università di Pisa and Istituto di Neurofisiologia CNR, Pisa, Italy)

As a consequence of a genetically determined misrouting of fibres at the optic chiasm, the Siamese cats' visual pathways are predominantly crossed, and neurons in areas 17 and 18 are driven almost exclusively through the contralateral eye. However, recent evidence has suggested that in

Siamese cats ipsilateral projections to the C1-lamina of the LGN are preserved to a greater extent than those of the A1-lamina. Since C1-C3 laminae provide the main input to area 19, we investigated the possibility that binocular interactions in area 19 may be differently organized than in areas 17 and 18. Of the 70 cells recorded in area 19 from eight cats 69 were strictly monocular, driven exclusively through the contralateral eye and only one neuron showed both strong contralateral and weak ipsilateral responses to visual stimulation. The general response properties of area 19 neurons did not differ from those described in ordinary cats. The lack of any consistent input through the ipsilateral eye in area 19 seems to indicate that the ipsilateral temporal input to C1-lamina is not cortically represented in this area.

- **Anterior ectosylvian visual area (AEV). I: Connectivity**
  M Norita, L Mucke, G Benedek, B Albowitz, O Creutzfeldt (Max-Planck-Institut für biophysikalische Chemie, D-3400 Göttingen, FRG)

- **Anterior ectosylvian visual area (AEV). II: Receptive field properties**
  L Mucke, B Albowitz, G Benedek, M Norita, O Creutzfeldt (Max-Planck-Institut für biophysikalische Chemie, D-3400 Göttingen, FRG)

The physiological properties of AEV in response to visual stimulation were investigated by extracellular recordings from single neurons in paralysed cats anaesthetised with Nembutal/N_2O. AEV neurons have large receptive fields that usually include the area centralis and do not show a clear retinotopic organisation. They are highly sensitive to rapid motion of small stimuli and various structured backgrounds (visual noise). Although most neurons responded to a range of different directions, the majority exhibited strong direction selectivity. There was a predominance of preferred directions towards the contralateral hemifield. Responsiveness was directly related to stimulus velocity and inversely related to stimulus length. The interaction between various properties (length inhibition, velocity preference, direction tuning) was investigated. In addition to testing the effects of moving spots and backgrounds independently, the effect of in-phase and antiphase motion of object and background was investigated by use of broad-band random-noise patterns in combination with spots at different relative and absolute velocities. The possible role of AEV in motion perception as well as certain functional similarities with the lateral suprasylvian visual area, the superior colliculus, the pulvinar, and the inferotemporal cortex of primates are discussed.

MOTION PERCEPTION

- **Perception of motion in equiluminous kinematograms**
  P Cavanagh, J Boeglin, O Eizner-Favreau (Psychologie, Université de Montréal, Montreal, Canada)

Rapid alternation between two fields of random dots that are identical except for a slight shift in a central square region produces a vivid impression of an oscillating square floating above the background. Although this cinematogram is easily seen in black-and-white, Ramachandran and Gregory report that no motion is visible when the dots are displayed in equiluminous red and green, and claim that their finding is consistent with a separate analysis of colour and motion in the visual system. We have repeated their experiments and find that equiluminous colour stimuli do in fact produce strong impressions of motion, although the range of alternation rates and displacements for which motion is seen is narrower than for black-and-white presentation. Ramachandran and Gregory used a 50 ms dark interstimulus interval (ISI) which we found to interfere strongly with motion perception, pushing it below threshold at equiluminance. The perception of motion for equiluminous stimuli with 0 ms ISI indicates that colour and motion are analysed conjointly by the visual system.

- **Apparent motion beyond the displacement limit: An analysis of short-range processes**
  W F Bischof, M Groner (Department of Psychology, Bern Universität, Bern, Switzerland)

The study of short-range processes with the use of random-dot cinematograms is complicated by the fact that motion information is integrated over a large field with motion detection units of varying receptive-field sizes. To avoid this problem we use rotating random-dot circles of varying diameters and dot densities. Experimental results show that the performance of detecting the direction of rotation does not just drop down to chance level beyond a certain displacement limit, but falls below chance level for certain larger displacements, indicating a reversed motion effect. Simulations using the Marr and Ullman model are in good quantitative agreement with these results.

- **Dynamic occlusion in the perception of depth structure**
  B J Rogers, M E Graham (University of St Andrews, St Andrews, Fife, Scotland)

The static occlusion of one surface by another is a valuable source of information for judgements about the ordering of depth surfaces and for figure/ground segregation. During active movements of an observer the progressive revealing and concealing of surfaces is the stimulus for dynamic occlusion. The rate of occlusion/disocclusion specifies here not only the relative ordering of the depth surfaces but also the magnitude of the depth difference. Under normal viewing conditions such information is confounded with the relative motion between surfaces at different distances which had been found earlier to specify depth structure accurately. In the present study, moving observers were presented with occlusion/disocclusion transformations in the absence of parallax cues. The results suggest that dynamic occlusion is capable of specifying either the direction or the magnitude of depth differences.

BINOCULAR INTERACTION AND STEREOPSIS

- **Persistence of depth perception with stabilized images**
  T Piantanida, R Hammon, H Crane (SRI International, Menlo Park, CA 94025, USA)

When a stereo image pair is positioned on the retinas with disparity, stabilisation of both retinal images results in the persistence of depth perception even though the binocularly perceived object disappears. Observers viewed stereo images of a fixation target and a vertical stripe in which the stripe was perceived to be at a greater distance than the fixation point. They judged when a matching stimulus appeared to be in the same plane as the fixation point or the vertical stripe. When the binocular images of the vertical stripe were stabilised to disappearance, observers saw a uniform field that appeared to be at a greater distance from them than the fixation point. The difference in the mean egocentric distance between the plane of the fixation point and the plane of the stripe was the same whether the stripe was visible or rendered invisible by image stabilisation. These results imply that an image need not be visible to support stereoscopic depth perception.

- **Configurations of motion in dichoptic vision**
  C Bonnet, D Williams (Laboratoire de Psychologie Expérimentale, Université René Descartes, Paris, France; CRESAP Neuroscience Laboratory, Northwestern University, Evanston, IL, USA)

When two random-dot patterns drifting in different directions are simultaneously seen in direct or in dichoptic vision, they do not generate the perception of a single configuration; on the contrary, a strong repulsion effect of their perceived directions has been reported. We assumed that these repulsion effects resulted from an inhibition between the orientation components of the stimulus and not from an interaction between its directional components. Williams and Sekuler (in press) have designed a system in which every dot within a pattern, instead of having a rigid linear track, follows a random walk around a mean direction. The orientation components of such stimuli are therefore low. When two such patterns which have different mean directions are shown together, a single configuration of motion is generally seen. A similar result is obtained when each of the two patterns is presented to a different eye. Thus, a configuration of motion can be observed in dichoptic vision as well as in monocular vision. Hence binocular rivalry effects depend upon inhibition between orientation components and not between directional components.

- **Phase-dependent and phase-independent depth aftereffects**

M E Graham, B J Rogers (University of St Andrews, St Andrews, Fife, Scotland)

Motion parallax and stereoscopic depth aftereffects are readily produced as a result of prolonged inspection of three-dimensional (3-D) corrugated surfaces. These aftereffects are phase-specific since, like afterimages, they depend on fixation of a particular part of the depth surface during the adaptation period. They can be measured by direct nulling with physical depth or by matching the perceived aftereffect to a depth surface falling on a neighbouring unadapted region of the retina. The latter method was used to study the effects of adaptation with the depth aftereffect 'superimposed' on a range of different 3-D surfaces. The results suggest that the site of adaptation is in mechanisms sensitive to changes of depth over space rather than to specific disparities. The depth-matching procedure was also used to investigate phase-independent depth aftereffects. In this case, adaptation to drifting and phase-alternating depth surfaces was found to reduce the matched amplitude of a subsequently presented suprathreshold depth surface by 20 to 40%.

- **Binocular interaction in induced movement**

M T Swanston, N J Wade (Dundee College of Technology, and Dundee University, Dundee, Scotland)

Dichoptic presentation of induced-movement stimuli has been examined by means of the video and zoom-lens procedure described by us earlier. Apparent rotation was induced in a line superimposed on a grating background, by radial expansion/contraction of the whole field. This controlled for problems arising from each eye tracking different directions of movement. The induced movement was greatly diminished by dichoptic presentation of line and background. This may have been due to the rivalrous suppression of the background at its points of intersection with the superimposed line, since our earlier work had shown the importance of this in the generation of the apparent rotation. The line itself was visible continuously, but did not appear to rotate. Thus in further experiments each eye viewed both line and background, but the direction of the induced rotation was made either discrepant or consistent by varying both background orientation and direction of field movement. The results show that the perceived movement is based on a combination of effects obtained when the field is viewed by either eye alone.

- **Dichoptic cancelling of opponent movements**

Ch M M de Weert (Psychological Laboratory, Universiteit Nijmegen, Nijmegen, The Netherlands)

Presentation of an expanding figure to one eye and of a contracting figure to the other eye leads to the interesting phenomenon of cancelling of movements, and to the occurrence of binocular standstills of fairly long durations. Figures used were circular patterns, with a spatial frequency of the rings of 3.3 cycles deg^{-1}, generated on a computer-driven television monitor. Velocities of (apparent) movement were varied from 1.5 to 0.3 deg s^{-1}. (A similar effect can be obtained with real movements if rotating spirals are used). The use of this type of moving stimuli, inward and outward, precludes eye movements which might favour perception of one of the two movements. Several variations in experimental conditions (movement in the same and in opposite directions, movement with equal and unequal velocities, phase differences between the two patterns) were introduced. The global outcome is that some kind of algebraic combination of the two monocularly perceived speeds seems to occur.

MODELING AND VISUAL INFORMATION PROCESSING

- **The processes of letter recognition**

L O Harvey Jr (Department of Psychology, University of Colorado, Boulder, CO 80309, USA)

Letter recognition can be a major testing ground for theories of visual processing. Letters are not equally detectable, and when recognition is not perfect they are not equally confusable. In order to test several models of visual processing, extensive data on letter confusions were collected. Six letter sizes were used ranging from 41 to 14 min of arc. Each letter size was presented at three or four contrast levels, such that overall recognition performance ranged from about 95% to 20% correct. The basic data are therefore in the form of 26 x 26 confusion matrices. Of particular interest is how the patterns of letter confusions change as both letter size and letter contrast are reduced. The ability of several models of visual processing, including template, feature, spatial frequency, and local processing, to predict these data is examined.

- **A linear-motion sensor**

A B Watson, A J Ahumada Jr (NASA Ames Research Center, Moffett Field, CA 94035, USA)

A model of a human visual-motion sensor is presented which is novel in three respects: (i) It is defined explicitly in two spatial dimensions and one time dimension. This allows us to compute its response to an arbitrary spatiotemporal stimulus. (ii) It is linear. This contrasts with previous models which use a nonlinear autocorrelation process. The use of a linear mechanism is more in keeping with the observed linearity of many visual cells. (iii) It is constructed largely out of known physiological mechanisms. The model consists of a temporal filter, resembling that of a ganglion cell or human observer, followed by odd and even spatial weighting functions. These weighting functions are oriented and selective for spatial frequency, and resemble simple cortical-cell receptive fields. The odd pathway then passes through a *hyperbolic filter* with unit gain and constant phase response of $\frac{1}{2}\pi$, at which point the two pathways are summed. The resulting mechanism will respond to motion exclusively in one of two directions. The behaviour of this sensor is discussed and compared to that of physiological mechanisms and to the psychophysical performance of the human observer.

- **Image analysis with local spatial-frequency channels**

R Röhler, W Schill, B Fischer, H Simmerl (Institut für medizinische Optik der Universität München, München, FRG)

There is evidence that spatial-frequency channels in the visual system are local, ie adaptation to a spatial frequency in one region of the visual field does not lead to intraocular transfer to another region. This favours the concept of image analysis by local spatial frequencies. Gabor's elementary functions have been used to investigate some aspects of image analysis by local spatial frequencies, eg convergence, calculation requirements, sensitivity against local changes in structure, etc. The adaptability of the human visual system to elementary Gabor functions has been investigated. Results are discussed in terms of the possible role of local frequency channels as a tool for pattern analysis.

- **Basic functions of a vector model of visual discrimination**

J P Thomas (University of California, Los Angeles, CA, USA)

The visual response to a stimulus may be represented by a vector in a multidimensional space. Each dimension represents the response of a single spatially-tuned mechanism. The ability to discriminate between two stimuli depends upon three things: the angle formed by the two vectors that represent the stimuli; the lengths of the vectors and the amount of random variability (noise). For grating stimuli, the angle formed by the vectors increases with increasing differences in spatial frequency and orientation, but is relatively independent of contrast. The functions relating the angle to differences in spatial frequency and orientation have been estimated from detection and identification data. The functions relating vector length and noise to contrast are more problematic. The ratio of vector length to noise increases with contrast. The increase is positively accelerated at contrasts below 0.01 and negatively accelerated at higher contrasts. Analysis of this composite relationship into the separate functions for vector length and noise is aided by experiments in which the effect of internal noise is minimised by the introduction of large amounts of external visual noise.

- **Tuning properties of masking functions for 2-D image discrimination**

M Hübner (Institut für medizinische Psychologie der Universität München, München, FRG)
T M Caelli (Department of Psychology, University of Alberta, Edmonton, Canada)

We have considered the conditions under which observers can discriminate two images, one consisting of a two-dimensional (2-D) band-limited noise-distribution, the other one consisting of the same noise-distribution but with a narrow-band signal ($\frac{1}{4}$ octave radial frequency and 2° orientation width) added. By properly adjusting the amplitude values of the image containing the signal we assured that both images had identical average luminance and contrast. The tuning properties of the masking effect exerted by the noise were investigated by varying the 2-D noise bandwidth with both signal and noise distributions centred at either 8 or 16 cycles deg^{-1} and at 90° orientation. Plots of the signal-to-noise energy ratios required for discrimination consistently reveal narrow bandwidths for the masking functions of about $\frac{1}{2}$ octave width and orientation tuning limits of approximately 10°. The tuning of this 2-D masking effect is therefore much narrower than would be predicted from results of studies involving 1-D grating patterns.

- **Coding images in the frequency domain: filter design and energy processing characteristics of the human visual system**

T M Caelli (Department of Psychology, University of Alberta, Edmonton, Alberta, Canada)

There is now a large amount of information on one-dimensional (1-D) broadband frequency channel characteristics of the visual system, but only recently have attempts been made to define additional 2-D narrow-band response profiles—particularly in central vision. Questions concerning the number, tuning widths, and phase sensitivity of such 2-D narrow-band coding units are reviewed. Results with gratings and 2-D images are discussed, particularly within the context of energy processing and information reduction strategies for the human observer. Finally, a consequent principle of univariance is defined and shown to hold with such filter units.

ADAPTATION AND COLOUR

- **Dark-adaptation of the human rod system**

K Nordby, B Stabell, U Stabell (Institute of Psychology, University of Oslo, Box 1094 Blindern, Oslo 3, Norway)

Dark-adaptation curves from a complete rod monochromat and a normal control subject were obtained, after substantial bleaching, with a Wright colorimeter. When adequate precautions were taken to ensure that the rod monochromat used the same retinal area when fixating during bleaching and dark-adaptation, the the dark-adaptation curves of both subjects were found to coincide following the cone/rod break. The rod monochromat showed no evidence of cone function during the early phase of the long-term dark-adaptation, irrespective of degree of bleaching and wavelength of test stimulation. In contrast to previous findings, which indicate that dark-adaptation curves from rod monochromats follow a single exponential function with a half-recovery of 4.5 min, and that there is a simple linear relationship between amount of rhodopsin still bleached and log threshold, the present results strongly suggest that the half-life of dark-adaptation curves in the human rod system is about 10 min, and show that the relationship between rhodopsin still bleached and log threshold is linear only in the region between 70 and 30% rhodopsin still bleached, but when the fraction of bleached rhodopsin is reduced below 30%, each percent unit of regenerated rhodopsin corresponds to an increasing fall in log threshold.

- **Effect of age-correlated changes in lenticular and macular pigmentation on dichromatic neutral points**

V J Volbrecht, J S Werner, R Kliegl (University of Colorado, Boulder, CO, USA)

We modelled the shifts in the wavelength loci of dichromatic neutral points associated with age-correlated changes in lenticular and macular pigmentation. The neutral point is the wavelength that produces the quantal-catch ratio:

$$\int_{380}^{720} Q_w \alpha \, d\lambda \Big/ \int_{380}^{720} Q_w \beta \, d\lambda,$$

where Q_w represents the quantal density of a specified, broad-band light (range: 2800-6600 K) and α and β represent the dichromat's two different photopigment absorption spectra corrected for preretinal absorption. These computations were carried out with the use of the Vos-Walraven primaries as absorption spectra and with varying densities of lenticular (0.5-2.5 at 400 nm) and macular (0.0-1.0 at 460 nm) pigmentation. Computations with average prereceptoral screening densities produced neutral-point loci that agreed (ca ± 1 nm) with mean, empirically determined values in the literature. The simulation of age-correlated increases in lens and macular pigmentation resulted in neutral-point shifts toward longer wavelengths. The magnitudes of the shifts associated with the range of preretinal pigmentation were: protanopes, 25 nm; deuteranopes, 24 nm; and, tritanopes, 13 nm.

- **Light-adaptation alters the relation between critical durations and latencies of photoreceptor responses**

G S Wasserman, L T Wang (Sensory Coding Laboratory, Purdue University, West Lafayette, IN, USA)

It has long been known that early or short-latency response features have briefer critical durations (time intervals during which a stimulus can affect neural response features) than later long-latency

response features, and also that light adaptation reduces both the critical durations and the latencies of neural responses. Do these two variables change commensurately when the state of adaptation changes?

Intracellular recordings were taken from photoreceptor cells of the Limulus eye exposed to light flashes of varying intensity and duration. A number of well-defined early and late response features were chosen for analysis. Latencies (L) were measured as the times between stimulus onset and the appearance of the response features. Critical durations (τ_{cr}) were measured as the stimulus durations above which changes in stimulus duration no longer affected the response features. Adaptation was controlled by varying the intensity of an adapting flash presented at regular intervals.

In dark-adaptation $\tau_{cr} = L - 31$ ms; in light-adaptation $\tau_{cr} = L/1.8$. Both results are qualitatively consistent with earlier reports but quantitatively indicate that adaptation disproportionately affects the two variables, implying that there is a late step in visual excitation which takes more time in light-adaptation than in dark-adaptation.

- **Prolonged visual afterimages with luminance modulation of the surround**
  J Gerling, L Spillmann (Neurologische Universitätsklinik mit Abteilung für Neurophysiologie, Hansastraße 9, 78 Freiburg i.Br., FRG)

A foveal afterimage is known to increase in duration when the luminance of the background on which it is seen is modulated in time. We observed an increase, although much weaker, when, instead of the luminance, the brightness was modulated by means of simultaneous contrast. The afterimage was produced by fixating a cross-shaped black mask (0.5 deg long, 0.12 deg wide), which was transilluminated by a photoflash. The duration of the afterimage was measured for three background conditions: (i) on a 5.8 deg uniform disk of 32.5 cd m^{-2} surrounded by a ring of equal width and luminance; (ii) on the same disk when the ring was luminance-modulated ($C = 0.58$) at 1 Hz—here the disk changed its apparent brightness in counterphase to the surround modulation; (iii) when the luminance of the disk was modulated together with that of the surround. Six subjects were tested eight times each for each background condition. Before each trial subjects adapted to 32.5 cd m^{-2} for 1 min; 5 min elapsed between successive trials.

Afterimage duration, relative to condition (i), increased on the average by 19% for condition (ii), and by 302% for condition (iii). We conclude that duration of an afterimage resulting from pigment bleaching is not only modified by subsequent modulation of the receptor input but also by postreceptoral processes such as those present in contrast induction.

- **The influence of the background on the propagation of inhibition**
  P C Vrolijk, G J van der Wildt (Department of Biological and Medical Physics, Erasmus Universiteit, Rotterdam, The Netherlands)

The effects of inhibition can be measured psychophysically by determining the frequency of seeing of a near-threshold stimulus. When jumping flashes (two elementary point flashes separated in both time and space) are used as a stimulus, the effect of inhibition can be detected with a high resolving power. This shows that inhibition is a dynamic process; it propagates with a velocity of about 3 deg s^{-1}. This velocity seems to be independent of the colour of the background and of the flashes. The background luminance influences the extent of inhibition, but does not alter the velocity of propagation. When no background field is presented, no inhibition is detected. When only a part of the background is illuminated, sometimes inhibition is found, and sometimes not. Systematic buildup and breakdown of the background field shows that inhibition only occurs when the distance between a luminous part of the background and the stimuli is less than the range of the inhibition effects (about $\frac{1}{2}$ deg).

VISUAL DEVELOPMENT

- **Maturation of spatial resolution and contrast sensitivity in the monkey's visual cortex**
  F Vital-Durand (INSERM, Unité 94, 16 avenue du Doyen Lépine, 69500 Bron, France)
  C Blakemore (University Laboratory of Physiology, Parks Road, Oxford, OX1 3PT, England)

We have shown earlier that the ability of neurons in the foveal representation of the lateral geniculate nucleus (LGN) of the monkey to resolve high-contrast drifting gratings increases gradually over the first year of life, from a maximum of 5 cycles deg^{-1} on the day of birth to better than

35 cycles deg^{-1} in the adult. This process is not substantially affected by deprivation of pattern vision.

Now we have used similar methods to measure spatial resolution and contrast sensitivity for neurons in the foveal area of the primary visual cortex. In normal monkeys, at each age the best cortical cells have spatial resolutions similar to those of the best LGN cells, and the peak contrast sensitivity improves, over the first year or more of life, from about 10 to about 100. However, binocular deprivation leads here, in contrast to the LGN, to an almost complete failure of spatial maturation. Cortical neurons in deprived animals (up to 130 days of age) have spatial resolutions and contrast sensitivities similar to those seen on the day of birth.

- **The development of peripheral visual acuity in human infants**
  R Sireteanu#, R Kellerer, K-P Boergen (Universitäts-Augenklinik, München, #Max-Planck-Institut für Hirnforschung, D-6000 Frankfurt, FRG)

We tested the development of visual acuity in a large group of infants under one year of age, using a method of forced-choice preferential looking. In part of these infants ($n = 64$), we tested the acuity of the central visual field. In other infants ($n = 60$) we tested the peripheral acuity, using as criterion the side of the first fixation of a peripheral stimulus. In both situations, the stimuli were square-wave gratings centred at a distance of 10 deg from the midline. Acuity of the central visual field increased by a factor 2.5 between 2 and 11 months of age. This result agrees with the development observed in other laboratories which used the same technique. Peripheral acuity showed a slower, but still significant increase. At all ages peripheral acuity was lower than the acuity of the central visual field. Even the youngest infants tested (2 months old) showed a superiority of the fovea over the peripheral visual field.

- **Development of pattern ERG in infants**
  M Pirchio, A Fiorentini (Istituto di Neurofisiologia del CNR, Pisa, Italy)

The pattern reversal electroretinogram (ERG) in response to high-contrast gratings reversed in phase at 6 Hz (12 rev s^{-1}) has been recorded in infants 2 to 6 months old by means of external electrodes applied to the lower eyelid. The high-spatial-frequency cutoff of ERG responses has been evaluated and compared with the high-frequency cutoff of simultaneously recorded cortical evoked potentials (VEP acuity). Between 2 and 6 months the VEP acuity improves with age in parallel with the changes in ERG acuity: at each age the two acuity values are approximately the same.

- **Infants' discrimination of spatial phase in compound gratings**
  J Atkinson, O J Braddick, J Wattam-Bell (Visual Development Unit, Department of Experimental Psychology, University of Cambridge, Cambridge, England)

The vision of young infants in some respects resembles adult peripheral vision. We have examined whether infants share the insensitivity of peripheral vision to the phase relationship of components in a compound grating. A habituation-recovery method with infant control procedure was used to test whether two groups of infants, aged 3-6 weeks and 8-13 weeks respectively, would discriminate between the first five harmonic components of a square-wave grating (fundamental frequency 0.18 cycles deg^{-1}), and the same sinusoidal components combined in random spatial phase. Both groups showed that they could make this discrimination, evidenced both by a recovery from habituation at a transition between the two stimuli and by a preference for the random phase over the square-wave components. This discrimination might be performed either by integrating information from harmonics in separate spatial-frequency channels, or possibly by detecting the difference in overall amplitude if the entire waveform could be processed by a single broad-band channel. To test whether infants' discrimination depends on the latter process, experiments are under way using a randomized variation of contrast in habituation and test presentations which excludes the use of overall amplitude as a cue for discrimination.

- **The development of spatial resolution in the pigeon retina**
  P Bagnoli, V Porciatti, R Barsellotti (Istituto di Fisiologia, Università di Pisa; Istituto di Neurofisiologia CNR, Pisa; Divisione Oculistica Ospedali Riuniti, Livorno, Italy)

Pigeons do not show skilled visual behaviour soon after hatching. Eyelid opening occurs at about 5 days and optical opacities are readily apparent. This prompted a study of the optical and neuronal factors affecting the maturation of spatial resolution in the pigeon retina. ERG responses to contrast reversal of patterned stimuli were recorded at different ages from the pigeon eye.

The highest spatial frequency for which a threshold response was present was taken as the retinal acuity. ERG responses to flashes of light were also recorded. The retinal acuity increased from 1.3 cycles deg^{-1} at 6 days to 4-5 cycles deg^{-1} at about 30 days. This value corresponds to the retinal acuity of adult pigeons. No flash-evoked ERGs were present during the first 4 days of life; thereafter a small ERG appeared. Its amplitude increased with age, reaching a value of 150 μV at 20 days, which corresponds to the adult value. These results indicate that a marked electrophysiological improvement occurs in the pigeon retina in the first month of life. The differential maturational gain of the flash-evoked and pattern-evoked ERGs in the first days following eyelids opening might be due at least in part to optical opacities. Refractive errors can be excluded, since additional lenses did not affect the pattern-evoked ERG amplitude.

AMBLYOPIA

- **Nasal hemianopia in deep amblyopia**

E Mehdorn (Universitäts Augenklinik, D-7800 Freiburg i.Br., FRG)

The nasal visual field of newborn kittens and human infants appears to be blind as compared to the temporal field. This binasal hemianopia disappears during the first weeks or months respectively. To find out whether the postnatal maturation of the ipsilateral retino-cortical projection can be disturbed by an interruption of binocularity and/or suppression of one eye, computer-assisted static perimetry was performed on strabismic patients with and without amblyopia and on patients with amblyopia but without strabismus. All amblyopes showed the well-known central scotoma. In 7 out of 14 cases with deep amblyopia and additional nasal hemianopia or a considerable constriction of the nasal field was found. Subjects with less severe amblyopia and nonamblyopic strabismic subjects showed only a slight constriction or small defects irregularly distributed over the field. These results allow the preliminary conclusion that the normal development of the ipsilateral retino-cortical projection is not disturbed by an interruption of binocular vision but by the continuous suppression of one eye.

- **Loss of acuity for stripes and letters at isoluminance**

P F Heard, R L Gregory (Brain and Perception Laboratory, Department of Anatomy, The Medical School, Bristol BS8 1TD, England)

Isoluminance—when colour and not brightness differences define borders—can be measured in various ways including minimum flicker photometry and minimally distinct border. There are dramatic perceptual losses around isoluminance, such as loss of Julesz's random-dot stereo depth, of apparent motion in alternated halves of a random-dot stereo pair, and of form perception in some types of pictures. The perceptual losses and lack of distinctness of border at isoluminance cannot be explained simply by loss of resolution, as degradation of the image with luminance contrast by blurring does not produce these losses or phenomena. Results from a study of acuity for stripes and letters around isoluminance are reported. Differences in these functions are discussed, with reference to amblyopia.

- **Amblyopic sensivity to 1-D and 2-D spatial phase**

C Weiß, I Rentschler, H Strasburger (Institut für medizinische Psychologie der Universität München, FRG)

One-dimensional (1-D) and two-dimensional (2-D) measures of amblyopic sensitivity to spatial phase were compared. Compound gratings were used to determine sensitivities to phase shifts between a sinusoidal fundamental and its third harmonic (Lawden 1982 *Human Neurobiology* **1** 56). Limits to 2-D phase processing were investigated by establishing at what contrast level a given phase quantisation yields discrimination of random checkerboard textures. Results with gratings confirm Lawden's results, ie that amblyopic phase processing is restricted to a narrower spatial frequency range than indexed by the contrast sensitivity function. Results concerning amblyopic discrimination sensitivities for phase-quantized textures differ from the results with gratings by being critically dependent on presentation time: 2-D phase resolution of amblyopic patients collapses at short exposure durations (50-125 ms). These findings cast doubt on the notion that phase sensitivities derived from measurements with 1-D complex gratings are predictive for the processing of 2-D 'natural' images.

- **Optic pathway anomalies and oculomotor disturbances in human albinism**
  P Apkarian, H Collewijn#, H Spekreijse, E P Tamminga# (The Netherlands Ophthalmic Research Institute, Amsterdam; #Department of Physiology, Erasmus Universiteit, Rotterdam, The Netherlands)

The relationship between aberrant optic pathway projections associated with albinism and aberrant oculomotor control was investigated. Visual evoked potentials and eye-movement recordings (electromagnetic) were obtained for 16 albinos. Monocular and binocular eye positions in darkness, during target fixation and tracking, and during induced optokinetic nystagmus (OKN) were measured under various stimulus and recording conditions. In our albino sample 14 subjects evinced spontaneous nystagmus. All albinos, however, showed eye-movement anomalies under specific stimulus conditions. Albinos with no spontaneous nystagmus showed horizontal OKN directional asymmetry with monocular partial field stimulation. Some albinos with spontaneous nystagmus showed inverted OKN. Cases with more severe spontaneous nystagmus, however, showed pseudo-inversion, ie the OKN pattern simply reflected the persistence of the spontaneous nystagmus. Although horizontal eye-movement disturbances could be found in all albinos, vertical eye movements remained relatively normal across all subjects.

- **Binocular visual perception in strabismics studied by means of visual evoked responses**
  E C Campos, C Chiesi (Department of Ophthalmology, Università di Modena, Modena, Italy)

Ten normal subjects and fourteen patients with concomitant esotropia were examined by means of pattern visual evoked responses (VERs) under monocular and binocular viewing conditions. When both eyes were stimulated together a VER summation was noted both in normals and in strabismics with small-angle deviation and anomalous retinal correspondence. This is considered an objective proof of binocularity. Patients with large-angle strabismus and/or suppression of the image of the deviated eye did not show summation. The significance of summation and its relationship with binocular vision was analysed by recording binocular VERs in normals in whom diplopia was artificially induced and in strabismics who spontaneously exhibited double vision. A simple way for differentiating normals from strabismics by means of VERs is presented, the presence or absence of summation per se not achieving this result. The method is based on placing in front of the fixating eye of neutral filters of increasing density. Summation disappears in strabismics with much weaker filters than in normals (0.5 versus 1.6 log units).

- **Asymmetry of monocular optokinetic nystagmus in humans with defective binocular vision**
  G Mohn, J van Hof-van Duin, R Sireteanu (Department of Physiology, Erasmus Universiteit, Rotterdam, The Netherlands; Max-Planck-Institut für Psychiatrie, München, FRG)

Amblyopic subjects with defective stereopsis often have asymmetric monocular optokinetic nystagmus (OKN), with the response to nasal-to-temporal (NT) stimulus movement reduced in comparison to the response to temporal-to-nasal (TN) stimulation. In order to clarify the relationship between monocular OKN, amblyopia, and foveal as well as peripheral binocular visual functions we tested six stereodeficient and six stereoblind subjects for binocular and monocular OKN at different stimulus velocities and field sizes. Ten of the subjects were tested for residual binocular interactions (binocular summation of acuity, interocular suppression, motion-in-depth) at various positions in the visual field. Asymmetric monocular OKN was observed in four mild and two deep amblyopes with greatly reduced or no foveal stereopsis, and varying degrees of peripheral binocular functions. Both the depth of amblyopia and the extent of binocular deficiency seemed to affect the degree of OKN asymmetry seen. Strong OKN asymmetry was also found in two nonamblyopic stereoblind subjects. Two deeply amblyopic stereoblind subjects showed a reduction both of the TN and of the NT components of monocular OKN, masking any asymmetry. Field size of the optokinetic stimulus could not consistently be related to areas of residual binocular interaction in the subject's visual fields. The results indicate a relation between monocular OKN asymmetry and extent of total (foveal and peripheral) residual binocularity, which in amblyopes seems to interact with the depth of the acuity loss.

VISUAL ILLUSIONS

- **Local and global processes in the Hermann grid illusion**
  T Trościanko (Brain and Perception Laboratory, Department of Anatomy, The Medical School Bristol BS8 1TD, England)

Concentric-receptive-field explanations of the Hermann grid illusion are incapable of predicting changes in the appearance of one intersection of the grid when, say, the orientation or the overall extent of the grid is varied. Recent results suggest that both of these factors significantly affect the perception of the illusion. Such results are important for two reasons. First, they may invalidate some of my conclusions (1982, *Vision Research* 22 1363-1369) about perceptive-field distributions, since the model used in my measurements was a purely local one. Second, they may allow us to decide when, and how, global processes do contribute to the illusion.

Experiments were carried out in which the increment-threshold technique was used to determine the strength of the illusion under both steady and moving fixation. The results suggest that factors which affect the overall perception of the illusion (eg grid extent) do not have a systematic effect on the illusion as measured in this way. Several questions then arise: (i) does the increment-threshold technique measure something quite unconnected with the illusion, or (ii) is the illusion affected not just by the apparent darkening of the intersections, but also by other, perhaps less local, factors? I shall argue that my technique isolates the local process, and offer some suggestions about the nature of the global effect.

- **Are visual illusions caused by spatial filtering?**
  B Lingelbach, R L DeValois#, H Chan# (Institute for Applied Physiology, Marburg, FRG; Department of Psychology, University of California, Berkeley, CA, USA)

Acute angles between intersecting lines seem to increase physically if the figure is low-pass filtered. Consequently the presence of low frequencies should be correlated to the overestimation of acute angles. To test this assumption the Poggendorff figure was presented in the classical line version, in a plain dot form, and in one consisting of 'Mexican hat' (mexhat)-shaped dots. This last luminance or colour profile was chosen to eliminate low spatial frequencies. The patterns were presented in black-white luminance and in isoluminant colour versions. The colours used were red and/or green on a yellow background. The subjects' task was to align the two halves of the oblique line. The illusion for the two dot forms was—after a learning period—significantly less than for the lines. For most observers it is not possible to discriminate between the matches for the mexhats and those for the dots in the achromatic luminance versions. On an average the illusion was less for the mexhats than for the dots in the coloured conditions. This result might be explained by the different contrast sensitivity functions for achromatic luminance and isoluminant colour gratings.

- **Three perceptual illusions: their meaning for perceptual theory**
  F Metelli (Istituto di Psicologia, Università di Padova, Padova, Italy)

Three perceptual illusions are demonstrated and analysed: apparent transparency, apparent rest, and the illusion of the hole. Apparent transparency is a phenomenon the study of which goes back to Helmholtz and Hering; it was later analysed chiefly by the Gestalt school, and more recently by Kanizsa and by me and my coworkers. The hole illusion is a topic the study of which is at its beginnings. It is the case where a hole becomes invisible, or, more exactly, is not present in the perceptual world. Conversely, a nonexistent hole may be perceived.

Apparent rest can be observed when a Maxwell disk (a disk divided in two sectors of different colours, rotating at a fusion speed) is gradually retarded. When the rotation is very slow, one of the two sectors, in general the minor one, is seen rotating on a stationary disk. The conditions have been modified to allow the phenomenon to be analysed, as it appears to be basic for the theory of the visual perception of motion.

- **Correlates of the perception of contour in the activity of cells in monkey visual cortex**
  R von der Heydt, E Peterhans, G Baumgartner (Department of Neurology, University Hospital, CH-8091 Zurich, Switzerland)

Responses of visual cortical neurons were analysed in alert, trained rhesus monkeys. Conventional stimuli (edges, bars, and lines) were compared with illusory contours. Among other stimuli were two bright rectangles separated by a gap, with a pair of notches on both sides of the gap. Moving the

notches caused the illusion of a dark bar moving in front of two rectangles. The gap was adjusted so that the stimulus straddled the response field of the cell under study. In area 18 many cells responded to this stimulus. A stimulus with a gap as wide as 4 deg visual angle could still elicit a response (field at 3 deg eccentricity). When the stimulus was modified by closing the notches with thin lines, so as to weaken the illusion, the neuron responses also weakened. Cells responding to this stimulus responded also to the border between two abutting line gratings and showed similar orientation tunings in response to either of these illusory contours and to conventional stimuli. Our results suggest that contours often named 'cognitive' originate in area 18.

- **Cézanne and Helmholtz**

M L Teuber (MIT, Cambridge, MA, USA)

The Cubists thought of Cézanne (1839-1906) as their forerunner. What in Cézanne attracted the Cubists? The Master of Aix was acquainted with the visual theories of Helmholtz, as derived from the *Optique physiologique* (1867) and his popular writings. Let us list certain Helmholtzian ideas known to Cézanne and later part of Cubist theory: (1) We *move* vis-à-vis the object; thus the static viewpoint of Renaissance perspective is reliquished in Cézanne's paintings. (2) We recognise in all perspective transformations of objects the basic forms of *cube, cylinder, cone, sphere*. (3) *We see with two eyes* (not one eye, as Renaissance perspective requires). Cézanne employed a *binocular relief*, but he also showed, like Helmholtz, how we can take the binocular image apart. (4) Cézanne's method of 'passage'—the tying together of foreground and background objects (thus flattening the picture space)—was advocated by Helmholtz as well. (5) Cézanne referred to the *sensations as abstract signs that have to be interpreted* in accordance with our intelligence like linguistic signs, an idea first advanced by Berkeley in 1709 and revived by Helmholtz. Cézanne believed (like Helmholtz) that we "learn to see", as we learn a language. These five points are discussed and illustrated.

PERIPHERAL VISION

- **Mirror-symmetric facilitation opposite to the blind spot**

F Schmielau, M F Schmielau-Lugmayr, C A Marzi#
(Institut für medizinische Psychologie der Universität München, München, FRG; #Istituto di Fisiologia, Università di Pisa, Pisa, Italy)

Pöppel and Richards observed that, in hemianopic patients with additional small scotomata in the opposite visual field, 'islands of vision' are present at mirror-symmetric positions with these scotomata in the contralateral hemianopic field. Since in normal subjects the blind spot resembles a local scotoma, tests were carried out to establish whether visual performance is facilitated in a mirror-symmetric region in the nasal hemifield. Measurements of simple reaction times (SRT) to small suprathreshold light stimuli were carried out on seven subjects at different eccentricities in the temporal and nasal field. SRTs generally increased with increasing eccentricity, but more so in the nasal than in the temporal hemifield. Within the nasal field of all subjects an area was found at a mirror-symmetric position with the blind spot in which SRTs were shorter by 15-20 ms than at neighbouring eccentricities. Since facilitation of SRTs opposite to the blind spot is also found in hemianopic patients, this effect probably originates in one or more mechanisms within one hemisphere rather than in the interaction between the two hemispheres.

- **Critical flicker frequency as a function of eccentricity in man**

A Raninen, J Rovamo (Department of Physiology, University of Helsinki, Finland)

Stimulus area, luminance, and eccentricity are known determinants of the critical flicker frequency (CFF); CFF increases wtih area and luminance; with increasing eccentricity CFF first increases and then decreases. However, experiments on grating perception and studies of cat retinal ganglion cells suggest that the prime determinants of CFF in man are (i) the number of ganglion cells stimulated, N, and (ii) the flux, Φ [$= LA$, where L is luminance and A is the size of receptive-field centre (Ricco's area)], and that the variation of CFF with increasing eccentricity results from decreasing ganglion-cell density and increasing receptive-field size. Experiments produced the following results: (1) CFF increased monotonically with eccentricity when Φ increased but N was held roughly constant by increasing stimulus area; (2) CFF decreased monotonically with increasing

eccentricity when N decreased but Φ was held constant by reducing L; (3) CFF became independent of visual field location when both determinants were held constant at all eccentricities. The results indicate that at all visual field locations CFF is determined by flux, Φ and the number of ganglion cells stimulated, N.

- **Photopic contrast sensitivity as a function of exposure duration at different eccentricities**
  J Rovamo, L Leinonen, V Virsu (Department of Physiology and Psychology, University of Helsinki, Helsinki, Finland)

Irrespective of exposure duration, binocular contrast sensitivity to sinusoidal gratings of 0.75 and 8.25 cycles deg^{-1} decreased with increasing eccentricity in the inferior visual field; the decrease was similar for different exposure durations. Eccentricity had no effect on temporal integration: the increase of contrast sensitivity as a function of exposure duration was similar at different visual-field locations. To eliminate the effect of retinotopical differences in ganglion cell density we scaled the gratings by the magnification factor, M, of the human striate cortex: stimulus conditions then become cortically equivalent at different eccentricities. With M-scaled gratings the decrease of contrast sensitivity with increasing eccentricity disappeared and the temporal contrast sensitivity functions became independent of visual-field location. The results support the view that at photopic contrast threshold spatiotemporal information processing in the postretinal visual system is independent of visual-field location and that many eccentricity-dependent differences previously reported result from the inhomogeneity of the density of retinal ganglion cells.

- ***Interhemispheric* difference in complex gratings discrimination**
  N Berardi, A Fiorentini (Istituto di Neurofisiologia del CNR, Pisa, Italy)

We reported previously that there is no interhemispheric difference either for the contrast-sensitivity function or the bandwidth ofs patial-frequency channels, evaluated psychophysically, but that for right-handed subjects there is a left-hemifield superiority in the discrimination of complex gratings differing in the spatial phase of their harmonic components. We have extended these findings in several directions: (1) Left-hemifield superiority in spatial-phase discrimination is observed not only for gratings presented successively in a two-alternative forced-choice procedure, but also for gratings presented simultaneously one above the other. (2) A left-hemified superiority seems to be present also for the discrimination of complex gratings differing in parameters other than spatial phase (contrast, or number of harmonics). (3) No lateralisation has been found in the spatial-frequency discrimination of simple sinusoidal gratings. (4) In left-handed subjects the lateralisation for the spatial-phase discrimination is, as expected, either negligible or in the same sense (left-hemifield superiority) as in right-handed subjects.

- **Uniformity of motion aftereffects and lower threshold of motion in near-peripheral and central visual fields**
  M J Wright, A Johnston (Department of Psychology, Brunel University, Uxbridge, Middx, England)

Motion aftereffects (MAEs) were measured after 60 s adaptation to drifting gratings. The subject's task was to adjust the rate of drift of a test grating until it appeared stationary. The test grating was the same contrast, location, and spatial frequency as the adapt grating and was presented for 2 s intervals interspersed by 6 s top-up adaptation intervals. The magnitude of the MAE, expressed as temporal frequency, increased markedly as the grating was increased in eccentricity (0-14 deg) or in spatial frequency. MAE versus eccentricity functions for different spatial frequencies collapsed into a single function when eccentricity was expressed in relative units (number of cycles below fixation). Temporal frequency tuning of MAEs peaked at 8-10 Hz, and the shape of the function was independent of spatial frequency and eccentricity. M-scaled plots of MAE versus spatial frequency at different eccentricities approximated to a single function. The lower threshold of motion (LTM) was equal for M-scaled stimuli, but was considerably smaller than the MAE; Thus the MAE results cannot be explained by variations in LTM. The results suggest that both MAEs and the 'stopped visual motion' phenomena to which they contribute are due to cortical mechanisms which are uniform for stimuli at different eccentricities scaled according to the magnification factor, M.

- **The induction of optokinetic nystagmus by central and peripheral stimuli**

I P Howard, M Ohmi (Department of Psychology, York University, Toronto, Canada)

Hood found that patients with central scotomata show less optokinetic nystagmus (OKN) gain than normals. Others have found that OKN gain is higher when the central retina is artificially occluded by an image-stabilised disk. But an artificial occluder provides a potential fixation target. Furthermore, in none of these studies was allowance made for the difference in contrast sensitivity or magnification factor between the central and peripheral retina. We established that an image-stabilised disk, seen against moving stripes, provides a fixation target. The central retina was therefore occluded by a featureless black band with no vertical marks or boundaries. Our OKN stimulus was a moving grating with sinusoidal luminance profile, which allowed us to control for contrast sensivity, spatial-frequency content, and magnification factor. The gain of peripherally driven OKN was found to collapse to a low value above a stimulus velocity of about 30 deg s^{-1}. The gain of centrally driven OKN, although falling below one at about 30 deg s^{-1}, did not collapse until the velocity reached about 80 deg s^{-1}. This difference must reflect a basic difference in OKN stimulus control between central and peripheral regions.

MISCELLANY

- **Multistable fluctuations of visual response**

F T Arecchi, R Meucci, L R Ronchi (Istituto Nazionale di Ottica, 6 Largo Fermi 50125, Firenze, Italy)

An experiment is described in which a target is brought to a range where 'recognition' is uncertain, either by a reduction of its angular size or by a decrease of the background illuminance. Across this range the target (a fragmentary or incomplete digit) takes on, in turn, the appearance of one of a set of familiar patterns. Both the relative rate of occurrence of a given biased pattern and its frequency in time fluctuation were found to be consistently related to the degree of degradation of viewing conditions. The experimental data are interpreted in the frame of a physical model which takes account of the stability (multistability) of visual responsiveness.

- **Pictorial simulation of the visual image at the photoreceptor level**

T R J Bossomaier, A W Snyder (Institute of Advanced Studies, Australian National University, Canberra, Australia)

Computer image processing was used to examine the interaction of optical image quality and the photoreceptor sampling mosaic of vertebrate eyes. Naturally occurring scenes were filtered through the photoreceptor mosaic with appropriate noise introduced. Particular attention was paid to the undesirable effects of undersampling. By direct visual inspection of the processed images the trade-offs between image fidelity and detectability of stationary and moving features can be assessed.

- **Electrophysiological measurement of spatial-phase sensitivity**

H Strasburger, I Rentschler (Institut für medizinische Psychologie der Universität München, München, FRG)

Spatial-phase information conveys image structure, and failure in encoding phase relationships seems typical for amblyopic vision. We studied electrophysiological correlates of phase sensitivity by recording steady-state evoked potentials elicited by one-dimensional complex gratings. Patterns consisted of 1st and 3rd harmonics where the spatial phase of the 3rd harmonic varied in time with frequencies F of 4 or 8 Hz. At a given spatial frequency response amplitude increased with the amount of phase shift whereas a reference phase away from which the shift occurred had no influence. Additional experiments were designed to establish whether VECP response depended upon activation of phase-sensitive mechanisms or merely on apparent movement. First, removing the stationary fundamental—which does not elicit a VECP response when presented singly—significantly altered the VECP. We can now vary the spatial frequency of the stationary grating component to distinguish between masking effects and interactions specific for harmonic frequency relationships. Finally, we can vary F at a given amount of phase shift to separate effects of velocity and displacement. We put special emphasis on the analysis of temporal phase lag values of the VECP. The latter were significantly less affected by intra- and interindividual variations.

- **The detection of dynamically occurring depressions in surfaces**
  J-P Trepp, A Gerber (Department of Behavioural Science, Swiss Federal Institute of Technology, Zurich, Switzerland)

In the ecological approach to visual perception one of the fundamental performances is the assessment of surface layouts. Natural surfaces are structured at various levels of size. Rocks, cliffs, pits, or holes for example—units at the level of metres—are embedded in larger-scale modulations such as mountains or hills. The experiments reported here attempt to determine the influence of a large-scale structure on the detection of local features. Perspective representations of an elementary surface were generated on a display by means of a computer controlled interactive picture-system. The task of the subjects was to observe the display and to give a response as soon as a change was noticed. This change consisted of a local depression of increasing distinctness and occurred on a location randomly selected by the control program. The results indicate that detectability of local changes is impaired where the curvature of the global structure is highest. A thorough analysis of the experimental data, taking into consideration the standpoint of the observer, shows complex interdependencies of pictorial variables and performance.

- **Form matching in human vision**
  G J Burton (Royal Armament Research and Development, Fort Halstead, Sevenoaks, Kent, England)

The overall aim of the work is to investigate whether there exists a basic set of spatial patterns which, when added, permit a match to be made to any arbitrary pattern. This 'form matching' is based on the idea of equivalence patterns (Ratliff and Sirovich 1978 *Vision Research* **18** 845-852). Do such equivalence patterns exist as true matches, or do they simply represent examples that lie within the discrimination or threshold limits of the visual system? A digital image processing system was used to generate test patterns and variable sets of matching stimuli consisting of edge transients and diffuse bars. The observer used as many of these stimuli as required. The positions, contrasts, and sizes of the stimuli were adjusted until perfect matches were achieved. The results for simple rectangular bar test patterns show that no true equivalence exists. There is no bias towards pairs of matching patterns that differ significantly in their profiles. This suggests that the equivalence concept is not valid in the sense of 'metameric' form matches. The results raise the question how to devise visual discrimination models for application to the assessment of image quality.

- **Westheimer functions for incremental and decremental visual time thresholds**
  W H Ehrenstein (Neurologische Klinik mit Abteilung für Neurophysiologie, Hansastraße 9, D-7800 Freiburg i.Br., FRG)

Westheimer functions are usually determined by measuring the intensity threshold for a small test spot centred on background disks that are varied in size. In this study, the intensity threshold was replaced by the time threshold, ie the minimal duration necessary to just detect a change of constant luminance. The test spot (4 min of arc) was either briefly flashed (increment) or briefly cancelled (decrement). Threshold durations were measured as a function of background size at eccentricities of 10, 30, and 50 deg on the nasal retina. Typical Westheimer functions were obtained. With increasing background size the time threshold first increased to a peak then decreased and finally levelled off. Whereas the incremental time threshold peaked at almost the same background sizes as found for intensity thresholds, the decremental time threshold peaked at approximately 0.3 deg larger diameter backgrounds at all eccentricities. In addition, the plateau of the decrement curve remained at a higher level than that of the increment curve. The results suggest different sizes of receptive field centres for on-centre and off-centre neurons in the human retina than those found in monkey and in cat for transient cells.

POSTERS

- **Measurements of spectral sensitivities of man by Fourier interferometric stimulation compared with other methods of determining spectral deficiencies**

R Adamczyk (Augenklinik der Universität München, Mathildenstraße 8, 8 München 2, FRG)

A selected patient group with different forms of congenital spectral deficiencies was tested by different methods of determining these deficiencies: the test of Ishihara and Stilling; saturated and non-saturated Farnsworth-Panel D15-test, and examinations by the Nagel anomaloscope. The group was also tested by Fourier interferometric stimulation (FIS), a method which allows us to determine the spectral sensitivity of the eye from an electroretinogram. These investigations were undertaken to find out how FIS results compare with the results obtained by other commonly used methods. FIS is discussed as a clinical diagnostic method which enables us to determine colour deficiencies with the highest reliability.

- **Movement-sensitive binocular neurons and their anatomical connections in the macaque lateral pulvinar**

L A Benevento (University of Illinois, Chicago, IL, USA)

Lateral pulvinar (PL) has reciprocal connections with the cortex, pretectum, and superior colliculus; and is in a nodal position to integrate a variety of visual inputs and modulate, in turn, many visual and visuomotor centres via its outputs. Units have $\geqslant 10$ deg, unilateral or bilateral receptive fields which can extend to the entire visual field and often include the fovea. Midbrain inputs correlate with shorter-latency properties, eg rate and intensity, while cortical inputs correlate with long-latency properties, eg orientation and binocular interactions. Responses to tangentially moving stimuli are uni-, bi-, or pan-directional. Units sensitive to movement in depth gave increased or decreased monocular or binocular responses to the nonlinear rate of change of size of approaching or receding stimuli. For units sensitive to tangential stimuli and also to one other, eg in-depth, the response to one stimulus was unrelated to the response to the other. This is true of complex binocular interactions which are unpredictable from monocular responses. Thus PL units have different midbrain and cortical input combinations that form responses which influence, in turn, cortical and brainstem centres.

- **Psychophysical evaluation of signal representation**

C Bianco, A Macerata, P Mancini (Istituto di Fisiologia, Clinica del CNR, Pisa, Italy)

We have investigated the detectability of a number of ECG abnormalities in three different types of representation: one-dimensional, two-dimensional (contourographic), and pseudo-three-dimensional (simulating perspective). Our approach is derived from the signal detection theory through a simulation of an ECG signal by means of a special-purpose device. The simulated signal added to some masking noise is presented to different observers whose responses under different representation methods are classified in terms of true positive and false positive for the determination of the Receiving Operating Characteristic. The study allows an experimental assessment of the comparative efficiency of the three types of representation for the detection of a number of ECG abnormalities to be made, so as to optimise routine clinical analysis.

- **A study of fixational eye movements using small stimulus movements**

J de Bie, G van den Brink (Applied Physics Department, Technische Hogeschool te Delft, PO Box 5046, 2600 GA Delft, The Netherlands)

No quantitative models have as yet been proposed for the systems that control fixation, possibly because a stationary target provides no input for the control systems, so that the only input consists of internal noise, that is unknown to us. It is not possible to describe a system with an unknown input on the basis of its output only. Therefore, experiments have been carried out that show that there is no difference between reactions to small target movements, and reactions in the case of retinal image displacements caused by irregular eye movements during fixation of a stationary target. Reactions in response to small movements have been used to develop a model for the control of eye position during fixation. This model describes the properties of the slow control

system, as well as the triggering of microsaccades. It is concluded that a subject's reactions in response to very small stimulus movements are the only means by which quantitative insight may be gained into the systems that control fixation.

- **Inhibitory effect of false targets in stereopsis**

K Bingushi (Department of Psychology, Chukyo University, Nagoya, Japan)

Cumulative disappearance time of stereopsis under fixation was measured to examine the interaction between different disparities, for which purpose several simple stereograms consisting of a few vertical lines were used. It was found that stereopsis disappeared for a longer period of time: (a) as the disparity increased in the single-line condition (local stereopsis), (b) as the lateral separation of two lines became narrower in the Panum's limiting case as well as in the two-line condition (global stereopsis), (c) as the difference of disparities became larger in the two-line condition, or (d) when the test line was in the middle rather than at the end in the three-line condition. These results may be explained by postulating that there are inhibitory effects from the false targets to the true targets in the binocular network and that the magnitude of inhibition might be in inverse proportion to the distance between them.

- **Ipsilateral and contralateral visual pathways: different sensitivity to monocular deprivation in kittens**

S Bisti, G Carmignoto (Istituto di Neurofisiologia del CNR, Via S. Zeno, 51, Pisa, Italy)

The effects of early monocular deprivation in kittens' striate cortex are well documented: only a minority of cells can be driven by the deprived eye in the binocular segment of area 17. Surprisingly, recent experiments with surface evoked potentials were not able to demonstrate the same degree of damage as that shown by single unit recording. We attempted to bridge this gap by means of a modified technique of recording visual evoked potentials (VEPs) in response to contrast reversing gratings. Instead of a surface electrode we used a micropipette inserted in area 17, both contralaterally and ipsilaterally to the unexperienced eye. In the area ipsilateral to the deprived eye the VEP contrast thresholds were found to be higher for the deprived than for the normal eye at all spatial frequencies; at a fixed contrast VEP responses from the unexperienced eye were found to be smaller. In the contralateral striate cortex the VEP contrast thresholds for the two eyes are more similar, but it is possible to demonstrate deficits of the deprived eye at high contrast, especially at low spatial frequencies.

- **Main aspects of visual pursuit in premature infants**

H Bloch (Laboratoire de Psycho-Biologie de l'Enfant, EPHE-CNRS, Paris, France)

Visual pursuit has been studied in premature infants of homogeneous ages and weights at birth. One group consisted of infants observed on their 8th day, and a second group consisted of infants observed between their 7th and 8th weeks of extra-uterine life. Target (a light point) was moved on a vertical versus horizontal axis, at a speed of 14 cm s^{-1}. Reflection from infant's eyes was recorded on a videotape. We compared the directions and lengths of pursuit, and the mean amplitude of saccades in the two groups. Significant differences were found. We noticed absence of stimulus fixation, with regard to the stimulus position and we analyzed the distribution of head rotations during the pursuit. Head movements seem to be triggered by the rotation of the eye in the orbit, when it reaches a maximum. These results have made us reconsider the difficulties experienced by premature infants in maintaining foveal fixation.

- **Neuromagnetic fields visually evoked by square-wave gratings in the upper and lower quadrants**

T Blum, R Bauer [Neuromagnetisches Labor (TUB/FUB) Abteilung Psychophysiologie, Eschenallee 3, 1000 Berlin 19, FRG]

Recording visual evoked neuromagnetic fields (VEF) is a very useful method for investigating the retinotopic organization of the human visual cortex. The primary objective of this study was to investigate the effect of stimulus size and spatial frequency on the contralateral VEF topography as measured on the scalp. It appears that the VEF amplitudes recorded from occiput in response to lower quadrant and vertical octant stimulation are greater than those in response to upper quadrant and horizontal octant stimulation. The polarity inversion of the VEFs 100 ms complex, observed after moving the recording location, defines the direction of the field-generating current dipole. In addition to the topographical investigation, dynamic aspects of the VEF to various stimulus parameters

were analyzed at fixed recording locations. Our results indicate a relationship between the spatial frequency of the stimulus and the temporal frequency of the response.

- **The relationship between space and time in the perception of stimuli moving behind a slit**
  C Casco (Department of Psychology, University College, London, England)

When a shape defined by a set of dots plotted along its contour is presented in a sequence of frames within the boundaries of a slit, and in each frame only the parts of the figure falling within this notional slit are displayed, a whole moving dotted shape is perceived. This phenomenon, known as 'aperture viewing' has been explained in terms of a process that stores and then reassembles the features of the stimulus. Using masking techniques and psychophysical measures we have shown that 'aperture viewing' collapses only when: (a) dynamic random-dot patterns are presented along with the dots defining the shape, (b) the interframe interval is very short (less than 15 ms, (c) no stimulus features for shape recognition are available in individual frames. These results are discussed in terms of the 'correspondence problem'. Correct correspondence between the dots comprising the stimulus occurs only for a defined range of interframe intervals and spatial displacement between dots. Some implications for the modelling of the 'short-range process' which mediates the perceived segregation of a coherently moving shape are investigated.

- **Detection and duration discrimination with long-wavelength lights**
  E J Casson (Smith-Kettlewell Institute of Visual Sciences, San Francisco, CA, USA)

A 2 x 2 alternative-forced-choice procedure was used to measure the relationship between detectability and discriminability of 20 and 300 ms, 1 deg, 670 nm test increments presented on either 580 nm or 650 nm backgrounds. Discrimination performance for tests presented on a 580 nm background was poor compared to detection performance. Performance in this condition was within the boundary predicted by a single-pathway model. This model proposes that both tests activate the same single pathway and discriminability is limited by the probability that just-detectable tests evoke different temporal patterns within that pathway. When tests were presented on a 650 nm background, discrimination performance was much improved, exceeding the limits specified by the single-pathway model. Statistical analyses reveal that the best explanation is that both tests activated either of two labelled pathways. Each pathway has some sensitivity to both tests, but one is more likely to be activated by the brief test and the other by the long-duration test. The relative sensitivity estimates are also consistent with field- and test-mixture results for long-wavelength lights.

- **Are visual moirés produced by accommodation changes?**
  P Denieul, C Bonnet (Laboratoire de Physique Appliquée du Muséum, Paris et Institut d'Optique, Orsay; Laboratoire de Psychologie Expérimentale, Université René Descartes, Paris, France)

Prolonged viewing of a periodic structure generates visual moirés on the figure and a persistency effect (smearing effect) on a homogeneous background. It has been suggested that these effects are due to changes in accommodation. The aim of the experiment was to show a direct relationship between psychophysical characteristics of these moirés and their persistency, and changes in accommodation in viewing the same figure. Visual stimuli were circular square-wave gratings of different spatial frequencies shown at 38 cm from the eye. Latency of appearance of the visual moiré and duration of its persistence were measured. Accommodation changes were recorded under identical conditions with a high-sensitivity infrared optometer. The power spectrum of micro-fluctuations of accommodation was of particular interest. Results show that if relationships between perceptual phenomena and accommodation changes do exist, they are not at all linear. The retinal stimulus generated by accommodation changes could contain the basic information for perceiving visual moirés. However, the streaming effect needs to take into account the neurophysiological effect of the 'zooming' of the retinal image.

- **Goal-directed saccades in complex visual environment: comparison of pre- and postsaccadic visual information determines the correction saccade.**
  H Deubel, C Zetsche (Lehrstuhl für Nachrichtentechnik, Technische Universität München, München, FRG)

Because of the complexity of our normal visual environment the selection of one target among many alternatives and its relocalization after the primary saccade must be essential functions of oculomotor processing for goal-directed eye movements.

Since conventional paradigms using isolated stimuli as targets cannot address these processes our subjects had to perform horizontal goal-directed saccades on an extended pseudo-noise pattern of vertical bars. The saccadic target was defined by a bright/dark inversion of a limited area 5 deg in the periphery. During the primary saccade this target area was displaced by 0.5 to 1 deg while the other part of the scene remained stationary. Since target area and background had similar structure it was not possible to recognize the position of the target nor did the subjects perceive its intrasaccadic displacement. Surprisingly, however, involuntary saccades occurred which accurately corrected the total refixation error. These data imply that the correction saccades are based on a comparison of a version of the selected area stored before the primary saccade with the actual postsaccadic input.

- **Perception of differences between optically and mechanically presented motion information**
  G Dörfel, H Distelmaier (Forschungsinstitut für Anthropotechnik, Wachtberg, FRG)

With the aim of modelling the interaction between visual and vestibular motion perception, we investigated human ability for difference perception between optically and mechanically presented motion information. Subjects sat in a laterally accelerated compartment and watched a moving belt indicator with vertical black and white bars on it. The velocity of the moving belt, representing an outside view, was increased or reduced by 20%, 40%, or 60% against the velocity of the compartment moving sinusoidally along a horizontal track. Subjects had to push a button when they perceived differences. The duration of button pushing was taken as a criterion for the ability of difference perception. A linear relationship between difference perception and motion variables is found only when a subjective scale is used for difference estimation. This subjective scale is directly proportional to the mechanical and inversely proportional to the optical motion variables. Difference perception is more sensitive for increased velocity of the moving belt with respect to the compartment than for reduced velocity.

- **Different approaches to the temporal impulse response of the visual system**
  T Elsner, G Hauske (Lehrstuhl für Nachrichtentechnik, Technische Universität München, München, FRG)

The temporal impulse response of the human visual system was determined by using two different methods: reaction time and threshold measurements. Reaction times were measured in a simple detection task with suprathreshold and subthreshold sinusoidal gratings exposed with various onset asynchronies. In another experiment detection thresholds of sinusoidal gratings were measured under identical experimental conditions. It is shown that on postulating a specific detection model in combination with a linear preprocessing unit the results obtained by the two methods can be made to fit a uniform theory.

- **Amplitude transition functions for small saccades in a target-tracking task**
  J Findlay, J Balmont (Department of Psychology, University of Durham, South Road, Durham DH1 3LE, England)

When a subject follows with his eyes a target which moves in a series of steps, an interesting situation can arise when the target makes two steps in quick succession. The second step may occur during the period of preparation of the saccade to the first step, and produce systematic modifications to this saccade. In particular, it is often found that the saccade amplitude varies systematically as a function of the interval following the second step. Becker and Jürgens (1979 *Vision Research* 19 967-975) used this to derive a model of the process of saccade generation. The experimental data on which this model was based came from a study in which target steps in excess of 15 deg visual angle were used. We have studied tracking with much smaller target jumps (1-5 deg). Many of the results with larger saccades are reproduced with small saccades, but some significant differences emerge. The temporal sequence of processing seems more tightly controlled for small movements. Transitional saccades are produced whenever the second step precedes the target by more than 80 ms, irrespective of whether or not this step takes the target to the opposite visual hemifield. In the former case, however, there is evidence of a strong inhibitory process, eventually resulting in delayed saccades to the second target position.

- **Conditions of occurrence and reaction times of express-saccades**
  B Fischer, R Boch (Neurologische Klinik mit Abteilung für Neurophysiologie, Freiburg i.Br., FRG)

Monkeys trained to fixate a small fixation spot can saccade to a peripheral target in as short a time as 70 ms after its occurrence when the previous fixation spot has been turned off 120–200 ms earlier, before (Fischer and Boch, 1983 *Brain Research* **260** 21–26), whereas regular saccades in the same situation have reaction times of about 130 ms. The rate of occurrence of such express (E)-saccades to a target in a given position increased from about 10% to 100% and their reaction times decreased from about 95 ms to 75 ms within a few days of training. The necessary condition of the occurrence of E-saccades is neither the ability to predict nor that to compute the target location in advance. It rather appears that for an E-saccade to occur the process of interruption of active fixation must be completed at the time when the new target becomes visible. In fact, when a monkey has learned to saccade to a peripheral target, while the fixation spot remained visible, he produces reaction times between 200 and 600 ms in most of the trials, whereas E-saccades occur only occasionally. The results allow us to decompose the process of the initiation of visually guided saccades into several sections that may be related to breaking fixation, decisionmaking, and computation of target position.

- **Spatial contrast and temporal modulation sensitivities in dark-reared cats under conditions of binocular and monocular viewing**
  E Gary-Bobo, Y Fregnac, B Grandjean (Laboratoire de Neurobiologie du Développement, Université de Paris-Sud, 91405 Orsay, France)

We established the contrast sensitivity function for stationary and drifting gratings by means of the conditioned suppression technique with a constant confidence level. Cats were deprived of visual experience from birth till the age of 7 or 12 months. Behavioural testing was performed one or more years after return to light. Constant-stimuli method was used to determine thresholds. A permanent reduction in contrast sensitivity was observed over the whole spectrum of spatial frequencies in the visually deprived cats; it was the greater the longer the period of deprivation. Modulation transfer functions were then established for different temporal frequencies. Temporal resolution appeared different when tested through each eye and significantly lower in monocular than in binocular viewing. As observed in normal animals, acuity diminished with increasing temporal frequencies, and appeared to be worse for the naso-temporal direction. These impairments in visual capacities and asymmetries in movement detection might be related to observations by other authors of anomalies in fixation and optokinetic nystagmus gain.

- **The time-order criteria in visual perception**
  L Giulio, E Camino (Istituto di Fisiologia Veterinaria, Torino, Italy)

There is much evidence that visual 'sensation' outlasts any brief light flash by at least 60–100 ms. Therefore, the detection of stimulus onset asynchrony between two short flashes (of 1 ms duration) presented in close succession, Δt, implies that a comparison is performed between two signals whose information codes partially overlap in the temporal domain. In our experiments a third flash was displayed at $\frac{1}{2}\Delta t$ between two flashes asynchronously presented: the spots, which formed the corners of an equilateral triangle, were observed binocularly; the image of the triangle was projected within the fovea. When the temporally interpolated stimulus is presented, the performance of temporal discrimination deteriorates and the duration of the temporal window for apparent simultaneity increases. Control tests were carried out with a flash presented a short interval after (or before) two other flashes simultaneously displayed. The results confirm that the perception of temporal discrimination in the presence of an interpolated stimulus may be ascribed to temporal information rather than to more complex spatial information.

- **Patterned spirals enhance the motion aftereffect**
  M W Greenlee, L Spillmann (Neurologische Klinik mit Abteilung für Neurophysiologie, Freiburg i.Br., FRG)

After observing a rotating spiral subjects see apparent counterrotation when the spiral is stopped. This motion aftereffect (MAE) has been attributed to the adaptation of movement-sensitive neurons, and is usually demonstrated with high-contrast spirals or gratings. However, since motion-sensitive cells respond primarily to edges, ie, transients, such stimuli may be not optimal. Therefore, we

asked whether an increase in the MAE could be induced by patterned spirals of low mean figure-ground contrast, but with a large number of edges. To test this hypothesis we used a four-armed white spiral containing randomly oriented Vs (chevrons) and rotated it in front of white, grey, and black backgrounds. For comparison, we inverted figure with ground and the spirals were either white, grey, or black. Spirals were rotated at 12 rev min^{-1} and adapting time was 30 s. A stationary black spiral on a random-dot background always served as a test stimulus. The patterned spiral on each uniform background produced a longer MAE than its inversion. Duration increased by 38, 8, and 26% for the white, grey, and black backgrounds, respectively. Interestingly, a MAE almost as strong as that found for the uniform backgrounds was obtained when the patterned spiral was rotated against an equally patterned background. Uniform spirals on the various uniform backgrounds produced lesser effects.

- **Information about 3-D shape in a square-wave grating projected on backgrounds of different complexity**
  K-A Gustafsson, J Putaansuu, S S Bergström (Department of Applied Psychology, Umeå Universitet, Umeå, Sweden)

We have shown earlier that square-wave gratings projected onto flat backgrounds tend to appear as three-dimensional (3-D) objects. More complex backgrounds (with a lot of stimulus information about their flatness) are more often reported to appear 3-D than simple grey ones. In the present experiments this effect of complexity was studied more systematically. Flat surfaces were illuminated by square-wave gratings of different contrast values. Six backgrounds of different complexities (chromatic and achromatic colours, and differences in contrast within the background) were used. The results indicate that a chromatic component facilitates the perception of a 3-D object even with minimal contrasts within the background. The results are discussed with reference to a vector analytic model for the perceptual analysis of reflected light into common and relative components carrying information about *illumination*, *colour*, and *3-D shape*.

- **Fourier components of checkerboard and plaid patterns seen in afterimages**
  F Heitger (Department of Psychology, Biomathematical Section, Universität Zürich, Zürich, Switzerland)

After adaptation to a checkerboard pattern in two alternating phase positions the fundamental and third-harmonic Fourier components of the checkerboard may be seen in the afterimages. The phase positions must be chosen so that some of the Fourier components are either in phase or in counter-phase with respect to the retina. Only in this 'interference-like' condition will the afterimage of the Fourier components adapted in phase be seen immediately after adaptation. After adaptation to a plaid pattern diagonal grids are seen as afterimages, even though the plaid does not physically contain any diagonal Fourier components. The diagonal Fourier components must be introduced by the visual system's nonlinear transfer function for luminance. By changing the luminance relationships in the plaid pattern it is possible to correct for this nonlinearity. When this is done, the afterimage of the diagonal Fourier components disappears at the point where the luminance relationships in the plaid pattern have been corrected for a logarithmic transfer function.

Explaining these effects calls for the presence in the visual system of a process combining spatial integration with selectivity for orientation, spatial-frequency, and phase. A possible candidate is the simple cell in the visual cortex.

- **Visual grouping without low spatial frequencies**
  L Jáñez (Mathematical Psychology, Universidad Complutense de Madrid, Madrid 3, Spain)

Gestalt psychologists have stressed the perceptual importance of grouping. On the basis of multichannel theory of early visual processing grouping has been attributed to the operation of channels tuned to low spatial frequencies. If this explanation is correct and sufficient, grouping should not occur when high-pass-filtered images are being viewed, because they do not excite low-spatial-frequency channels. Evidence is presented, however, that visual grouping also occurs for such stimuli. Hence a more comprehensive explanation of visual grouping is needed.

- **Aiming precision and temporal characteristics of saccades**
  Z Kapoula (Groupe "Regard" Paris V, currently at Durham University)
  J Findlay (Department of Psychology, Durham University, South Road, Durham, DH1 31E, England)

Saccades are traditionally considered ballistic responses in the sense that once triggered they can not be modified. A demonstration that the peak velocity of a saccade can be voluntarily modified presents strong evidence against this idea. At present some data show that saccadic velocities may be varied under some conditions (training, biofeedback). In a recent experiment, which was designed to test the existence of a speed-accuracy trade-off, we compared peak velocities of saccades produced under a condition requiring saccades of high accuracy and saccades produced under another condition requiring saccades of lower accuracy. The results show that more variability occurs in the peak velocities of saccades under the high-accuracy condition. In addition the subjects who present this effect show a weak or nonexistent oculomotor-latency-saccade-accuracy trade-off. This result can be interpreted as a voluntary effort to correct saccade accuracy during its execution. Further experiments are in progress to investigate this result.

- **The effect of an area of coexistent stimuli on perceived illumination and correlation between perceived illumination and surface lightness**
  A Kozaki, K Noguchi (Tokyo Women's Christian University, Tokyo; Chiba University, 1-33 Yayoicho, Chibashi, Japan)

It is known that the illumination judgments of a surface are strongly influenced by the luminance of highlights or white areas of this surface, but only few systematic studies have been made of the factors affecting perceived illumination. In this study the effect of an area of coexistent stimuli on perceived illumination and the relationship between perceived lightness and perceived illumination was examined. Two types of category judgments for the lightness of light stripes and perceived overall illumination were made under the condition where the relative area of dark stripes in a grating target was varied. It was found that the slope of the plot of perceived illumination against the logarithm of illumination did not depend on the relative area of dark stripes, whereas the latter affected correlation between perceived lightness and perceived illumination. The albedo hypothesis, which states that the 'registered' illumination is a causal condition for the perception of surface lightness, is thus not supported.

- **Standardization of clinical contrast-sensitivity measurements**
  B L Lundh, S Arlinger (University Hospital, Linköping, S-581 85 Linköping, Sweden)

Simple quantification of the findings must be made possible. There is also a demand for clear graphical presentation, when relating recordings from an individual to the range of normality, and when comparing recordings made on different occasions and recordings obtained from different patients. Similar requirements in audiology have led to the development of the internationally standardized audiogram. For contrast-sensitivity measurements the demands are met by Bodis-Wollner's visuogram (1976 *Nature* **261** 309-311), in which an individual's results are related to normal reference values. Minor modifications that increase the value of the visuogram are suggested. Three different dB-scales, directly comparable to the three dB-scales that are in use in clinical audiometry, are defined. The rational basis for the definitions is argued, and the application of the dB-scales in visuograms is illustrated with clinical examples.

- **A psychophysical study of the Fuchs phenomenon**
  S C Masin (Istituto di Psicologia, Università di Padova, Padova, Italy)

Studies of phenomenal transparency have so far been primarily concerned with patterns in which the object jutted out under the transparent layer, and four phenomenal surfaces interacted. Algebraic models have been proposed to explain this kind of transparency. However, as long ago as 1923 Fuchs showed that transparency is perceived even when the object does not jut out under the transparent layer, and only three surfaces interact. This kind of transparency, termed here as the Fuchs phenomenon, lacks explanation. The achromatic colour conditions that rule the Fuchs phenomenon were studied. By means of a numerical rating method, it was found that the perceived degree of transparency depends on the difference in lightness between the object seen through transparency and its background, and that the colour of the object seen through transparency is equal to the reduction colour of the object itself. Contrary to Koffka's assumptions, this second

result shows that the Fuchs phenomenon is in fact a special kind of transparency to which the scission models of phenomenal transparency do not apply.

- **Contrast sensitivity function in humans visually deprived in early life by bilateral congenital cataracts**

L Mioche, M T Perenin (Laboratoire de Neuropsychologie Expérimentale, Bron, France)

It has been suggested by animal and clinical findings that the mechanisms responsible for the central vision with its high spatial resolving power rely more on early visual experience than those related to peripheral vision. We investigated this further by measuring the contrast sensitivity function (CSF) in the central and peripheral visual field of six subjects with deprivation amblyopia resulting from bilateral congenital cataract compared to nine normal subjects. In central vision the CSF for sinusoidal stationary gratings was dramatically impaired in the medium- and high-spatial-frequency range, but relatively spared in the lowest-spatial-frequency range in all six amblyopic subjects. In peripheral vision at 10 deg of eccentricity the CSF was also impaired and surprisingly to the same or even greater extent than in central vision, but equally so in both nasal and temporal visual fields. Although the correction of aphakia by glasses might disadvantage peripheral vision, this can hardly be the single cause of the peripheral CSF loss. The transient mechanisms are being studied in the same subjects.

- **Human velocity coding in central and peripheral visual field**

G A Orban, F Van Calenbergh, H Maes (Katholieke Universiteit te Leuven, Laboratorium voor Neuro- en Psychofysiologie, Campus Gasthuisberg, B-3000 Leuven, Belgium)

Just noticeable differences in velocity were measured by the method of constant stimuli and expressed as Weber fractions. Plots of these Weber fractions, $\Delta\omega/\omega$, as a function of reference velocity, ω, ranging from 1 to 512 deg s^{-1}, yield a 'velocity discrimination' function which is U-shaped for foveal vision. In the present experiments velocity discrimination curves were compared for central vision and peripheral vision (10, 20, 30, and 50 deg eccentricity). The results show that the depth of the U-shaped curve and its upper velocity branch hardly change with increasing eccentricity, but the lower velocity branch shifts progressively towards higher velocities. The same results were obtained with the slit width adapted to spatial resolution at each eccentricity and not adapted, and with low and high contrasts. A control experiment showed that velocity discrimination was similar for stimuli presented in the upper, lower, nasal, or temporal parts of the visual field. The results are in agreement with the hypothesis that velocity-tuned cells underly velocity discriminations since the range of their optima shows the same changes with eccentricity as just noticeable differences in velocity.

- **Modulation sensitivity functions and the receptive fields of ganglion cells in pigeon**

M A Pak (Physiologisches Institut II, Universität Düsseldorf, D-4000 Düsseldorf, FRG)

Modulation sensitivity functions (MSFs) of retinal ganglion cells of the pigeon (*Columba livia*) were determined by recording impulses from their end branching in layer III (*Stratum griseum et fibrosum superficiale*) of the optic tectum as response indicator. The stimuli were pattern reversals of square-wave gratings with various spatial frequencies. The modulation of the stimuli was constant (55%); mean luminance was 20 cd m^{-2}. The MSFs of individual ganglion cells fall into three groups with different dependencies on spatial frequency. The inverse Fourier transformation of a MSF is taken to represent the line-spread function of a ganglion cell, depicting its receptive-field profile. The line-spread functions exhibit a centre-surround organisation in the receptive field. Receptive-field diameter ranged from 0.28 deg to 2.30 deg for centres, and from 0.75 deg to 14 deg for surrounds.

- **Visual cells selective for type of movement and stimulus form in the temporal cortex of the macaque monkey**

D I Perrett, P A J Smith, A D Milner, M A Jeeves (Psychological Laboratory, University of St Andrews, St Andrews, Fife KY16 9JU, Scotland)

We investigated whether cells in the anterior superior temporal sulcus (STS) have responses contingent both on stimulus form and on motion. We were able to classify preferred type of movement for 208 STS cells; 105 cells were also selective for stimulus form, many responding only to face or body movements. Cells selective for form were present in all classes of motion sensitivity encountered. Translation: 40% of cells responded to lateral translation or to motion in

depth. 10 cells responded to the limb movements made during walking. Appearance: 30% of cells responded transiently to stimuli as they moved into view (both centrally and peripherally), but not to static stimuli or to the onset of movement of stimuli already in view. Rotation: 30% of cells responded to rotation in a particular plane. Many responded specifically to the rotation of the face from profile to confront the monkey (15 cells) or to the face rotating away (10 cells). Results suggest that analysis of form from movement may proceed by independent computations of form from restricted types of motion information.

- **Temporal adaptation in a movement-sensitive neuron of the blowfly**
  R R de Ruyter van Steveninck, H A K Mastebroek (Department of Biophysics, Rijksuniversiteit te Groningen, Westersingel 34, 9718 CM Groningen, The Netherlands)

In order to study the effect of stimulus parameters on the visual processing of moving objects, we recorded spike activity in a wide-field movement-sensitive neuron of the blowfly (*Calliphora erytrocephala*). The response to stepwise moving square-wave patterns can be characterized by an exponential decay of activity in the p.s.t.h. The decay time constant is roughly proportional to stimulus interstep time in the range of 5-200 ms. In contrast, spatial as well as intensity parameters of the stimulus leave this time constant virtually unaffected. Furthermore, its value is found not to be determined by the neuron itself, but by peripheral local visual processing. We interpret the adaptation of the p.s.t.h. time constant to the stimulus interstep time as a scaling property of the visual system that specifically optimizes temporal resolution.

- **Influence of colour and luminance on the Müller-Lyer illusion**
  K J Sadza, Ch M M de Weert (Psychological Laboratory, Katholieke Universiteit Nijmegen, Nijmegen, The Netherlands)

Arrowheads and line of the Müller-Lyer figure were varied independently in colour and luminance. Stimuli were presented on a computer-controlled colour-television monitor. Subjects judged according to a forced choice yes-no method. Results show the following: (1) Differences in colour between arrowheads and line reduce the illusion. (2) Luminance differences between arrowheads and line always reduce the illusion. (3) Effects 1 and 2 are independent of each other. (4) With a dark background, if the arrowheads are brighter than the line the decrease is smaller than if the arrowheads are darker than the line. (5) A total change of luminance does not affect the illusion. Results 1 and 2 contradict Wickelgren's contrast hypothesis, which predicts a maximum illusion with arrowheads maximally different from the background and the line minimally different. However, result 4 prevents an explanation purely in terms of similarity. Therefore, a combined model of contrast and similarity is proposed.

- **The Hermann grid effect under different conditions of illumination**
  U Savardi, N Saviolo (Istituto di Psicologia, Università di Padova, Padova, Italy)

Tests were carried out to find out whether the illusion is equally pronounced at the intersections of black lines (white squares) and at the intersection of white lines (black squares) and varying conditions of illumination and intersquare distance. The numerical scaling method was used. Preliminary results show that (a) in both types of grids the effect is stronger under high than under low illumination; (b) the black-line white-square grid produces a stronger illusion than the white-line black-square grid at a low level of illumination.

- **A multi-parametric investigation of simple reaction times to visual stimuli**
  M F Schmielau-Lugmayr, F Schmielau (Institut für medizinische Psychologie der Universität München, München, FRG)

We measured simple reaction times (SRTs) to suprathreshold visual stimulation, to establish a relation between hand dominance and visual field position. Stimuli were presented monocularly and binocularly at central and peripheral locations on the horizontal and vertical meridians of two right-handed subjects. Simple reactions were performed with the dominant and with the nondominant hand. The results were as follows: (1) Peripheral stimulation resulted in longer SRTs than foveal stimulation on the horizontal and vertical meridians. (2) SRTs on the vertical meridian were longer than SRTs at corresponding stimulus locations on the horizontal meridian. Whereas SRTs were shorter in the lower than in the upper visual field for both hands, on the horizontal meridian an ipsilateral hand-field advantage was found. On the vertical meridian the dominant hand was superior. (3) Responses under binocular viewing conditions were significantly

shorter than under monocular conditions. (4) Though mirror-symmetric facilitation is found at a location opposite to the blind spot, SRTs for visual stimuli at other locations on the horizontal and vertical meridians are not changed when preceded several seconds by stimulation of a mirror-symmetric position.

- **Interaction between the processing of the visual bar stimulus dimensions of position, width, and contrast**

  S Shechter, S Hochstein (Life Sciences Institute Hebrew University, Jerusalem, Israel)

Our aim was to examine the interactions between the processing of three dimensions of a bar stimulus: its position, its width, and its contrast. Integral dimensions show facilitation in correlated tasks and interference in orthogonal tasks; separable dimensions show neither of these effects. Psychophysical tests were performed by four subjects with normal vision. We found that position and width are integral dimensions. There is both redundancy gain in correlated tasks and interference in orthogonal tasks. However, we found an asymmetric, hierarchical relationship between the processing of these dimensions and the dimension of contrast. The position and width dimensions influence the judgement of contrast, but contrast influences neither judgement of position nor judgement of width.

- **The influence of stimulus shape on the fixation point**

  J F van Sonderen, J de Bie, G van den Brink (Applied Physics Department, Technische Hogeschool te Delft, PO Box 5064, 2600 GA Delft, The Netherlands)

Experiments have been carried out to find out whether stimulus shape has an influence on the fixation point. The stimulus consisted of a bright cross, and the subjects were instructed to fixate the intersection point of the two perpendicular lines. When the horizontal line was shifted horizontally, while the vertical line remained in place, so that the point of intersection did not move, the gaze direction changed slightly in the same horizontal direction. In another experiment the horizontal and the vertical lines were both moved horizontally, but by unequal amounts. The size of the reaction saccade was not the same as the size of the jump made by the point of intersection. The new gaze direction corresponded then with a point that was located on the longest of the two sections of the horizontal line. It is concluded that while fixating an object, the visual system seems to determine some weighted 'centre of gravity' of the light distribution in the retinal image.

- **Absolute depth judgements based on vertical disparities**

  P Stenton, J P Frisby (Department of Psychology, University of Sheffield, Sheffield S10 2TN, England)

Mayhew and Longuet-Higgins have recently proposed a computational theory of stereopsis which shows how fixation distance can in principle be derived from vertical disparities, and they have advanced a new interpretation of Ogle's induced effect which suggests that the human visual system does indeed utilise the method they have identified. A further prediction of their theory as a model of human stereopsis is that it should be possible to demonstrate that judgements of absolute depth are better for certain arrangements of dot targets presenting vertical disparities than for otherwise similar targets that do not. We report a series of psychophysical studies on this theme designed to test the prediction.

- **Evidence for adaptive independence of rods with large fields obtained from field displacement and field additivity tests**

  J F Sturr, J P Gaska, K L Church (Vision Laboratories, Department of Psychology, Syracuse University, Syracuse, NY 13210, USA)

Most studies have shown that rods will adapt independently of cones if the adapting field is large. However, most studies employed either only two wavelengths or a few luminance levels. We used a wide range of adapting-field wavelengths and retinal illuminances. All stimuli were presented in Maxwellian view, 5 deg temporally to the left eye. The test probe was 30 min visual angle, 25 ms, and concentric with the steady adapting field (AF). For the field-displacement experiments, increment threshold (IT) curves were measured for six AF wavelengths from 450 to 700 nm and AF intensities up to the level of rod saturation. The results support adaptive independence. We also applied the more stringent test of field additivity. Field additivity refers to the fact that for a univariant mechanism, once the IT is established for two wavelengths, the IT obtained on any

combination of the two fields is strictly determined. We thus measured ITs on AFs produced by superimposing two fields of different wavelengths: the intensity of one field remained constant while that of the other was increased in steps. The results show that the increment threshold curves follow univariance exactly, thus supporting the independence of rod adaptation upon large steady fields.

- **Are meridional variations in the orientation-discrimination performance of the cat dependent on line length?**
  E Vandenbussche, G A Orban, H Maes (Laboratorium voor Neuro- en Psychofysiologie, Katholieke Universiteit te Leuven, Campus Gasthuisberg, B-3000 Leuven, Belgium)

Just noticeable differences (jnd) in line orientation were determined behaviourally in a 'Berkley box', in which the percentage of correct responses are measured as a function of the orientation difference between two simultaneously presented lines. Both lines were presented simultaneously, but the cat could see only one at a time. For each line length just noticeable differences were measured in an interleaved fashion for a principal (horizontal or vertical) orientation and for an oblique orientation. If 75% of correct responses are taken as differential threshold, data from two cats show that for long line length (12 deg) orientation discrimination is much better for principal orientations (jnd = 2.7°) than for oblique ones (jnd = 5.25°) Decreasing the line length to 1 deg reduced the discrimination performance for principal orientations, but left the performance for oblique orientations virtually unchanged. Hence in the cat, as in humans, the oblique effect in orientation discrimination decreases with decreasing line length.

- **Are meridional variations in human orientation discrimination caused by a decision rule anisotropy?**
  R Vogels, G A Orban, E Vandenbussche (Laboratorium voor Neuro- en Psychofysiologie, Campus Gasthuisberg, B-3000 Leuven, Belgium)

Orientation discrimination is determined by two serial processes: a sensorial one leading to a neural stimulus representation used as input for the second—a decisionmaking—process. Meridional variations in orientation discrimination are assumed to be the result of a visual cortical anisotropy similar to the S cell anisotropy of cat and monkey's area 17. This report is concerned with the possible contribution of meridional differences in decision rule (bias and strategy)—an element of the decisionmaking process—to this oblique effect. Line orientation discrimination was measured for different meridians in five experimental designs: three types of a temporal two-alternative forced-choice procedure, the Matin and Drivas signal detection task, and the method of constant stimuli. Hypotheses about the decision strategy used were tested by comparing the performance for these five designs. Differences of a factor two were observed between experimental designs, but these were meridian independent. The results indicate that the oblique effect in orientation discrimination *cannot* be explained by differences in decision rule.

- **Elementary movement detectors**
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The optic ganglia of the fly, the lamina, the medulla, and the lobula complex are built of periodic ordered columns of neurons. The retinal mosaic structure is mapped retinotopically onto these columns such that each column corresponds to a certain optical axis in the visual field of the compound eye. In the lobula plate a wide-field neuron, the H1, is horizontally selective in its movement-detection performance. The movement detection can be described by the so-called 'correlation model': comparison takes place between two visual elements which sample space over a basic distance defined by the retina mosaic. The contribution of correlators, with a sampling base of n-fold (n = 1, ..., 4) of the basic sampling distance (retina grid constant), has been studied by using the 'far-field' method. In this case it is possible to stimulate every single neural input channel of the retinal array by a time sequence of light flashes. The preliminary results show that reaction of several n-fold correlators can be elicited. The contributions of 1-, 2-, and 3-fold correlators to the movement response have different weights.

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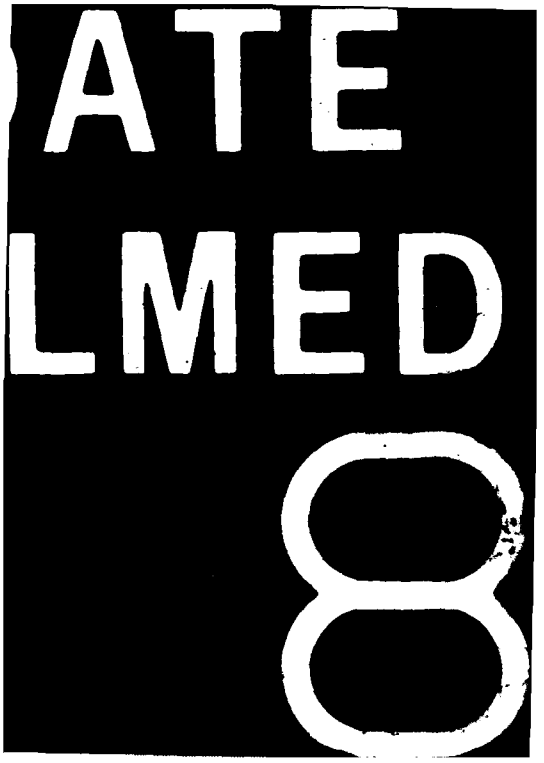
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